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NASCAP USER'S MANUAL

M. J. MANDELL, J. M. HARVEY AND I. KATZ

SYSTEMS, SCIENCE AND SOFTWARE

PREPARED FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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16 Abstract

The NASCAP (NASA Charging Analyzer Program) code simulates the charging process for a complex object in either tenuous plasma (geosynchronous orbit) or ground test (electron gun source) environment. This volume contains detailed specifications needed to run the code. The physical content of NASCAP is described in NASA CR-135256.

The object definition section, OBJDEF, allows the test object to be easily defined in the cubic mesh. The test object is composed of conducting sections which may be wholly or partially covered with thin dielectric coatings. The potential section, POTENT, obtains the electrostatic potential in the space surrounding the object. It uses the conjugate gradient method to solve the finite element formulation of Poisson's equation. The CHARGE section of NASCAP treats charge redistribution among the surface cells of the object as well as charging through radiation bombardment. NASCAP has facilities for extensive graphical output, including several types of object display plots, potential contour plots, space charge density contour plots, current density plots, and particle trajectory plots.

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SUMMARY

The NASCAP (NASA Charging Analyzer Program) code simulates the charging process for a complex object in either tenuous plasma (geosynchronous orbit) or ground test (electron gun source) environment. NASCAP is written in FORTRAN V and runs under EXEC-8 for UNIVAC 1100 series computers. This volume contains detailed specifications needed to run or modify the code. The physical content of NASCAP is described in NASA CR-135256.

The object definition section, OBJDEF, allows the test object to be easily defined in the cubic mesh. The test object is composed of conducting sections which may be wholly or partially covered with thin dielectric coatings. It is built of rectangular parallelepipeds and objects having slanted surfaces (WEDGE, TETRAHEDRON). Complex objects such as an octagonal right cylinder (OCTAGON) and a twenty-six faceted quasi-sphere (QSPHERE) may be explicitly defined. The different conducting sections may be floating, held at fixed potentials, or biased relative to one another.

The potential section, POTENT, obtains the electrostatic potential in the space surrounding the object. It uses the conjugate gradient method to solve the finite element formulation of Poisson's equation. The potential is defined in the inner mesh containing the test object, and in an arbitrary number of nested outer meshes having successively doubled grid spacings. (This enables treatment of a large volume of space exterior to the object.) To promote efficiency of the potential solver at each timestep, several potential scaling options are available to produce "initial guess" potentials based on a previous set.

The CHARGE section of NASCAP treats charge redistribution among the surface cells of the object as well as charging through radiation bombardment. In the ground test case the incident flux is determined by forward particle tracking from an electron gun of specified beam characteristics. In the plasma case the incident flux may be determined by the reverse trajectory sampling method, or by a Maxwell probe approximation. In all cases energy- and angle-dependent formulations for electron backscatter and secondary electron emission due to incident protons and electrons are used. A full shadowing treatment is used in computing photoemission due to incident sunlight. A first-order explicit photosheath treatment is available, and a "LONGTIMESTEP" option allows timesteps of one minute or more during differential charging.

NASCAP has facilities for extensive graphical output, including several types of object display plots, potential contour plots, space charge density contour plots, current density plots, and particle trajectory plots.

1. INTRODUCTION

1.1 WHAT IS NASCAP?

The NASCAP code was developed by Systems, Science and Software under contract to NASA-Lewis Research Center to simulate the charging process for a complex object in either tenuous plasma (geosynchronous orbit) or test tank (electron gun source) environment. A block diagram of the NASCAP code is shown in Figure 1.1. The focus of the code is the CHARGE section, which calculates the fluxes to the surface elements of the object and the resulting material response. The particle tracking capabilities of the code are included in the CHARGE section. The POTENT segment is a conjugate gradient (CG) Poisson solver for the electrostatic potential on and about the object. The potential may be calculated in an arbitrarily large volume through the use of successively coarser outer grids. The OBJDEF segment allows definition of an object composed of bare or dielectric-coated conductors. The surfaces of the object may be normal to any of the twenty-six symmetry directions of the cubic mesh. The HIDCEL segment calculates the portion of each surface cell exposed to sunlight. Graphical capabilities of the NASCAP code include object display, particle trajectories, and contours of electrostatic potential, space charge, or test tank current.

NASCAP has been written in FORTRAN V and runs under EXEC-8 system for UNIVAC 1100 series computers. It has been tested and installed on the UNIVAC 1108 at S^3 using the S^3 graphics library, and on the UNIVAC 1110 at NASA-LeRC using both the FR80LIB and LEWIGS graphics libraries. Core storage requirements are minimized by extensive segmentation and use of fast block transfer between core and scratch files. NASCAP runs in approximately 70K words (decimal) of core. We believe NASCAP to be transferable to any medium to large size computer having a word length of 36 bits or longer.

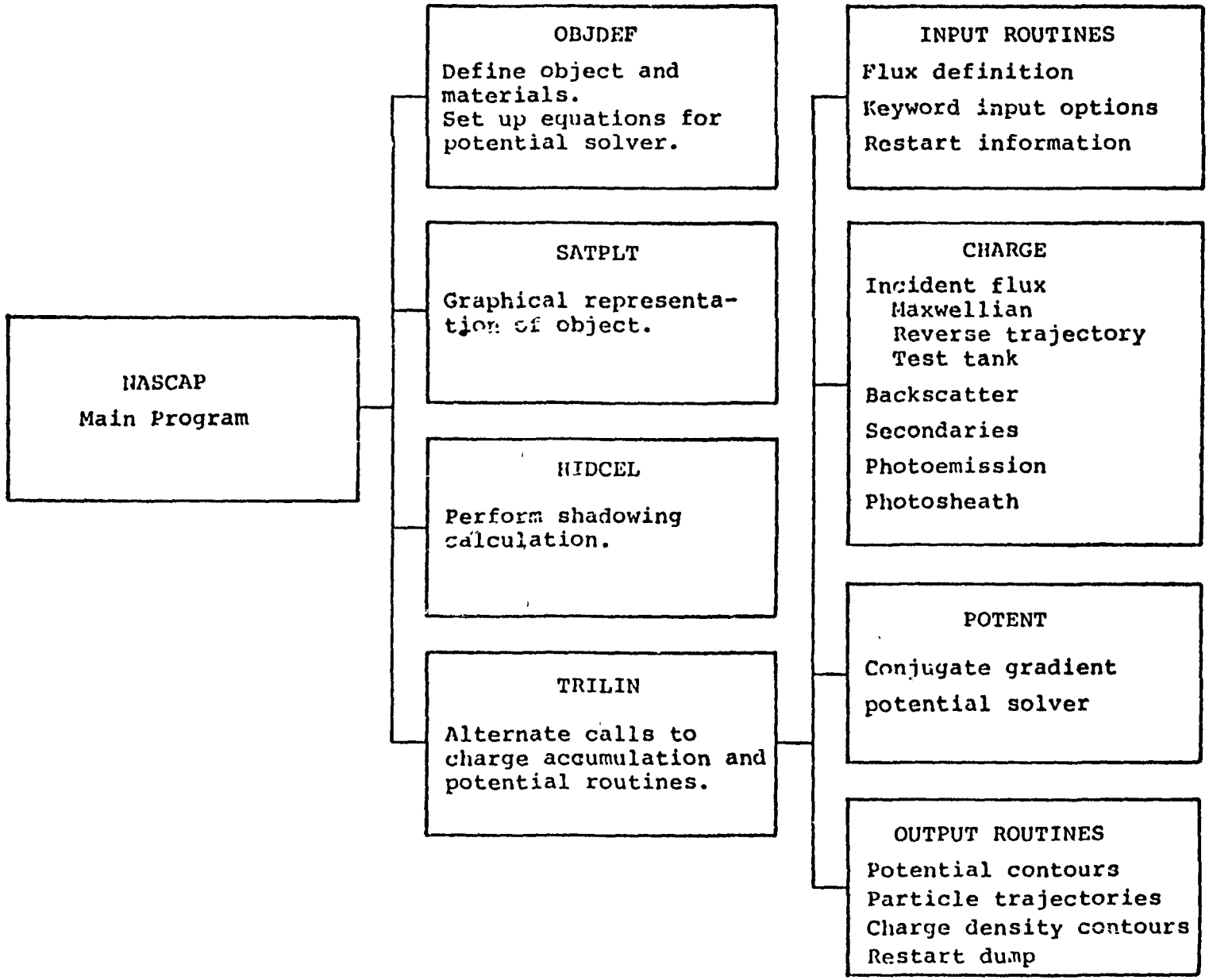


Figure 1.1. Block diagram of the NASCAP code.

1.2 WHAT DOES NASCAP DO?

NASCAP simulates the charging process in an explicit time-stepping fashion. Suppose that at a particular time we know the charge distribution on the object, the electrostatic and magnetostatic fields about it, and a description of the environment. NASCAP first calculates the flux of electrons and ions incident upon each surface cell of the object. In the test tank case this is done by tracking particles forward from the electron gun source, whose characteristics are known from calibration data. In space this may be done either by approximating each surface element as a surface element of a spherical probe in an isotropic Maxwellian plasma, or by sampling the plasma distribution using reverse trajectories from the satellite. The latter method automatically takes particle shadowing into account. Next, electron backscatter and low energy electron emission are taken into account, including a full treatment of sunlight shadowing. Optionally, currents and space charge due to the low energy emitted electrons may be calculated by particle tracking.

The fluxes calculated above are assumed to hold for a user specified time, and the charges on the satellite are updated accordingly. The second portion of a time step is the calculation of the electrostatic field about the object in the presence of the new charge distribution. The solution of Poisson's equation about a complex three-dimensional object is a large task which can easily come to dominate the cost of a charging simulation. NASCAP uses a sophisticated conjugate gradient iterative scheme to solve a finite element formulation of Poisson's equation. Startup, restart, and potential scaling features enable the user to provide a good starting point for the iterative process, and thus minimize the number of iterations required to achieve a potential field with tolerable levels of error. When the new potential has been calculated, the charging process for the next time step can begin.

1.3 WHAT DOES NASCAP EXPECT FROM ME?

Because NASCAP is a very general, very flexible code, a great deal of user input is required:

1. The object to be tested must be defined geometrically and electrically.
2. The properties of the surface materials of the object must be characterized.
3. The environment in which the simulation is to take place must be defined.
4. The necessary computational resources must be made available.
5. The user must determine the timescale of the simulation.
6. The user must provide parameters concerning the size of the computational space and the level of accuracy of various parts of the simulation.
7. Intelligent choices must be made among the various options provided.

1.4 HOW DO I USE NASCAP?

Because NASCAP consists of several complex modules combined into one very complex code, it is not easy to use. In this section we discuss some strategies and tactics for carrying out a NASCAP simulation, postponing detailed input specifications to subsequent chapters.

1.4.1 Computational Space and Object Definition

NASCAP focuses on an "inner grid" of dimension $17 \times 17 \times 4n+1$ ($4 \leq n \leq 8$) within which the object is located. Outer grids have similar dimension but successively double the physical mesh spacing. The first task of the user is to

determine the smallest computational space which allows for adequate representation of the object, and thus minimize the effort and expense required for the simulation. A simple object can often be run as a one-grid problem. A typical space test for a complex object filling most of the inner grid will be run as a two-mesh problem, with monopole boundary conditions on the outermost surface. Complex tank test cases have been run with a truncated third grid to provide the proper tank aspect ratio.

It is recommended that, for all but the very simplest objects, the object definition input be developed piece by piece using NASCAP's OBJDEF-only mode. The main structure should first be plotted on quadrille paper and defined. NASCAP's printed and graphical output can then serve as an aid to adding various features and appendages. Complex appendages (such as curved solar panels) can be defined separately and later added to the main object definition file. Finally, the defined object should be carefully checked before proceeding with the simulation.

1.4.2 Flux Definition; Operating Modes

The calculation of the flux to the object dictates the mode of operation of the CHARGE portion of NASCAP. The three flux-types are (1) the monoenergetic electron gun source; (2) the Maxwellian probe approximation; and (3) reverse-trajectory sampling.

For the monoenergetic electron source the user is required to provide the current density as measured on a calibration plate. NASCAP automatically determines the number of particles to be tracked forward to reproduce the input calibration to reasonable accuracy. The user should verify the accuracy using the printed and graphical current density output. NASCAP automatically compensates for the presence of a constant magnetic field.

The Maxwellian probe approximation is the simplest and fastest operating mode. The environment is specified by the four parameters of ion and electron temperature and density. Since the angular distribution (isotropic) can be treated analytically, electron backscatter and low energy electron emission reduce to one-dimensional integrals. The most severe shortcoming of this approximation is the neglect of particle shadowing.

The reverse-trajectory particle-pushing mode is the slowest operating mode for NASCAP. This is because good resolution requires a reasonable density of particles on the three-dimensional space of energy, polar angle, and azimuthal angle, resulting in a very large number of particles. Given the user-specified numbers of energies and angles, NASCAP chooses their values in an optimized manner. The distribution sampled can be either a Maxwellian or can be taken from experimental data. Data from selected ATS-5 observations are provided with NASCAP.

1.4.3 Floating, Fixed, Biased and Coupled Conductors

The object defined by NASCAP may be composed of up to seven conducting sections. By default, all conductors are floating and are coupled only through the fields in the empty space surrounding the object. The "Keyword" input provides a medium for altering these specifications.

Typically, the main coupling between two conductors is the capacitance through a glue joint or dielectric spacer. NASCAP accepts this information through the "CIJ" keyword.

Any conductor may be held at fixed potential relative to plasma ground or test tank ground. The potential solver will then change the charge stored on that conductor as necessary. Since the total charge on the object is not held constant, one should not use monopole boundary conditions

(see next section). Holding a conductor at fixed potential improves the convergence rate of the potential solver.

Conductors may be biased relative to conductor 1, which is considered to be spacecraft ground. This results in redistribution of charge among the conductors. Monopole boundary conditions may still be used.

1.4.4 Use of the Potential Solver; Initial Potentials; Potential Scaling

NASCAP's potential solver is discussed in detail in Chapter 7. As with any iterative scheme for solving differential equations, the first few iterations consist of rapid local adjustment to minimize the residuals, followed by slow global drift toward the correct solution. By providing a good initial guess upon entering the potential solver, the second process becomes less important than the first, and thus the required number of iterations is minimized. The efficiency of the potential solver is decreased as dielectrics and vacuum gaps are made thinner; it is increased when potentials on conductors are fixed.

At the start of a simulation the potential may be set to zero everywhere (using IOUTER = 0) or to a monopole (Q/r) potential (using IOUTER = 2). If a previous set of potentials is available for the same object, they may be scaled for the new run (using IOUTER = -n). Since the potentials on the outer surface of the computational space are never changed by the potential solver, the initial guess also serves to define the boundary conditions. We recommend IOUTER = 0 for the test tank case, and IOUTER = 2 for the space cases.

NASCAP provides the capability to scale the potential at the beginning of a simulation, and at each cycle prior to entering the potential solver. By default, the potential is scaled in proportion to the total charge ("SCALE") unless

conductor 1 is fixed ("NOSCALE"). The third option ("DSCALE") scales the potential according to

(total charge) - (charge on fixed conductors).

This option is recommended for the test tank with a grounded conductor.

We recommend that the number of potential iterations, MAXITR, be in the range $10 \leq$ MAXITR ≤ 50. The first ten iterations usually eliminate most of the error in the potentials. Beyond fifty iterations the algorithm becomes subject to roundoff error. Large numbers of iterations are usually required only in the early stage of a simulation. Here we suggest either a short time step, a potential restart, or the temporary fixing of conductor potentials. For an object with no differential charging, no potential iterations are required after the initial cycle, since the potential scales with the total charge.

1.4.5 Choice of Time Step; LONGTIMESTEP Option

The timescales involved in spacecraft charging range from 10^{-5} - 10^{-3} seconds for formation of a photosheath about a positive object, through 10^{-3} - 10^{-1} seconds for an object to charge negatively in a magnetospheric substorm, to 1 - 1000 seconds for differential charging. At the beginning of the simulation a fairly short time step should be taken until a satisfactory potential solution is achieved. The time step can then be lengthened as the net current decreases. In a multicycle run, this can be done through the input variable DELFAC.

The explicit timestepping procedure becomes unstable when

$$\frac{dJ}{dQ} \gtrsim \delta^{-1}$$

where J is the net current, Q is the total charge, and δ is the time step. This situation is likely to happen when an object is charging positively (so that the derivative is large) or during differential charging (when a large δ is desirable). For these cases the LONGTIMESTEP option should be invoked. This option causes the fluxes at the advance time step to be calculated using scaled potentials, and, if necessary, the current fluxes corrected using a first-order implicit scheme. The use of the LONGTIMESTEP option is <u>not</u> recommended in the presence of fixed conductor potentials, or when the "SHEATH" option is invoked.

1.4.6 Treatment of Low Energy Electrons; The "SHEATH" Option

In the default ("NOSHEATH") mode low energy emitted electrons (secondaries and photoelectrons) are treated simply as positive incident currents if the emitting surface is negative. For an electron-attractive emitting surface, this current is reduced by exp $(-\vec{E}\cdot\vec{\Delta}/2)$ where $\vec{E}$ is the field at the emitting surface, $\vec{\Delta}$ is the outward normal with a length of one grid unit, and the characteristic emitted energy is 2 eV.

If the "SHEATH" option is invoked, the electrons constituting the currents described above are tracked, starting with 2 eV energy normal to the emitting surfaces. The space charge associated with these electrons is calculated for use by the potential solver. The associated currents are used to correct the fluxes to each surface cell, thus taking into account any photocurrent from one part of the satellite to another.

2. NASCAP RUNDECK AND INPUT SPECIFICATIONS

This chapter contains specifications and examples for the NASCAP rundeck and three of the four user-supplied input files required by NASCAP. The specifications for the object definition input appear in Chapter 6.

2.1 NASCAP FILES AND RUNDECK

2.1.1 NASCAP Files

NASCAP uses a substantial number of external files. Since the major portion of the rundeck is devoted to the assignment, allocation, and/or copying of these files, it is appropriate to discuss them prior to discussing the rundeck.

NASCAP external files (Table 2.1) may be divided into three main categories:

1. User-generated input files. These are the flux and object definition files, the keyword input file, and the runstream input.
2. Scratch files.
3. Code-generated files required for restart. These contain potentials, charge distributions, and object definition information. (If no restart is contemplated, they may be regarded as scratch files. The IAREA file may be regarded as a restart file if successive runs are done with the same sun orientation.)

EXEC 8 and NASCAP necessarily communicate file references by Logical Unit Number (LUN) or dataset reference number (DSRN). The values suggested in Table 2.1 are those to which we at S^3 have become accustomed, and will be used in all examples. However, the LUN's are all input values and thus at the user's discretion.

Table 2.1. NASCAP Files

LUN/DSRN [Variable (suggested value)]	Type	Purpose
IP (10)	R, N	Potential Array Storage
IAUN (11)	S, N	Conjugate Gradient
IR (12)	S, N	Conjugate Gradient
IY (25)	S, N	Conjugate Gradient
IU (13)	S, N	Conjugate Gradient
ISPARE (14)	S, N	Conjugate Gradient
IROUS (15)	R, N, a	Charge Density
IPCOND (16)	R, F	Potentials on Conductors
IQCOND (17)	R, F	Charges on Conductors, Cycle, Time
IOBJ (18)	R, N	Object Information for Potential Solver
IOBPLT (19)	R, F, b	Object Information for Plotting, Charging
ISAT (20)	U	Object Definition Input File
ICNOW (21)	R, N	Surface Charge
IFLUX (22)	U	Flux Definition Input
IKEYWD (26)	U	Keyword Input
IAREA (27)	S, N, c	Shielded Areas for Photoemission
IPART (28)	S, F, d	Particle Plot Data
(Runstream) (5)	U	File Numbers; Run Options

NOTES

U - User input file

R - Code generated file needed for restart

N - NTRAN file

F - Fortran unformatted file

S - Scratch file

a - Needed for restart of potential calculation only

b - Negative to bypass object plots

c - Negative to bypass area calculation

d - Set zero to bypass particle plotting

2.1.2 The NASCAP Rundeck

The NASCAP rundeck contains the EXEC 8 system commands required for execution of NASCAP. It performs (in order) the following functions:

1. The @RUN card sets priority, charge number, time limit, etc.
2. Necessary file assignments and copy operations are performed.
3. A copy of the NASCAP absolute element is secured.
4. The system is instructed to execute NASCAP.
5. The runstream input file is supplied.
6. A postmortem dump may be requested.
7. Copy operations may be performed to prepare for subsequent restart.

In the examples which follow, we adopt the following conventions:

1. All LUN's take the values suggested in Table 2.1.
2. Catalogued files are assigned for exclusive use (@ASG,AX). Conversely, all files so assigned are assumed to be catalogued.
3. NASCAP communicates only with user files and scratch files. Restart files are copied into scratch files prior to execution and updated afterward. (This prevents their loss due to abnormal termination.) Such catalogued files are named 10A., etc.
4. The NASCAP absolute element is assumed to exist under the name NPROG.PGM.

5. The runstream, flux definition, object definition, and keyword input data are denoted [RUNSTREAM], [FLUX], [OBJECT], [KEYWORD] respectively. Files containing these data are assumed named RUNSTREAM., FLUX., OBJECT., and KEYWORD.

```
@RUN  .   [RUN CARD INFORMATION]
@ . THIS RUNSTREAM IS SELF-CONTAINED, EXCEPT FOR THE ABSOLUTE ELEMEN.
@ . NO RESTART IS MADE OR CONTEMPLATED.
@ASG,T 10.
@ASG,T 11.
@ASG,T 12.
@ASG,T 13.
@ASG,T 14.
@ASG,T 15.
@ASG,T 16.
@ASG,T 17.
@ASG,T 18.
@ASG,T 19.
@ASG,T 20.
@DATA,IL 20.              . OBJECT DEFINITION
[OBJECT]
@END
@ASG,T 21.
@ASG,T 22.                . FLUX DEFINITION
@DATA,IL 22.
[FLUX]
@END
@ASG,T 25.
@ASG,T 26.                . KEYWORD INPUT
@DATA,IL 26.
[KEYWORD]
@END
@ASG,T 27.
@ASG,T 28.
@COPY,A NPROG.PGM,TPF$.PGM
@XQT
[RUNSTREAM]
@PMD,GED
@FIN
```

Example 1. A self-contained runstream involving neither restart nor catalogued input file.

```
1.    @RUN  .   [RUN CARD INFORMATION]
2.    @ . A NORMAL RUN WHICH MAY BE A RESTART AND MAY REQUIRE RESTART.
3.    @ . ALL USER INPUT FILES (EXCEPT POSSIBLY RUNSTREAM) ARE CATALOGUED.
4.    @ASG,AX 10A.                  . RESTART FILES
5.    @ASG,AX 15A.
6.    @ASG,AX 16A.
7.    @ASG,AX 17A.
8.    @ASG,AX 18A.
9.    @ASG,AX 19A.
10.   @ASG,AX 21A.
11.   @ASG,T 10.                    . SCRATCH FILES
12.   @ASG,T 11.
13.   @ASG,T 12.
14.   @ASG,T 13.
15.   @ASG,T 14.
16.   @ASG,T 15.
17.   @ASG,T 16.
18.   @ASG,T 17.
19.   @ASG,T 18.
20.   @ASG,T 19.
21.   @ASG,T 21.
22.   @ASG,T 27.
23.   @ASG,T 28.
24.   @COPY 10A.,10.               . COPY RESTART FILES TO SCRATCH FILES
25.   @COPY 15A.,15.
26.   @COPY 16A.,16.
27.   @COPY 17A.,17.
28.   @COPY 18A.,18.
29.   @COPY 19A.,19.
30.   @USE 20,OBJECT               . OBJECT DEFINITION
31.   @ASG,AX 20.
32.   @COPY 21A.,21.
33.   @USE 22,FLUX                 . FLUX DEFINITION
34.   @ASG,AX 22.
35.   @ASG,T 25.
36.   @USE 26,KEYWORD              . KEYWORD INPUT
37.   @ASG,AX 26.
38.   @                            . OBTAIN ABSOLUTE ELEMENT
39.   @COPY,A @PROG.PGM,TPF$.PGM
40.   @XQT
41.   [RUNSTREAM] OR @ADD RUNSTREAM.
42.   @PMD,GED
43.   @COPY 10.,10A.               . COPY SCRATCH FILES TO RESTART FILES
44.   @COPY 15.,15A.
45.   @COPY 16.,16A.
46.   @COPY 17.,17A.
47.   @COPY 18.,18A.
48.   @COPY 19.,19A.
49.   @COPY 21.,21A.
50.   @FIN
```

Example 2. A runstream appropriate to restart and using catalogued input files.

```
@RUN  .   [RUN CARD INFORMATION]
@ . THE SAME AS PREVIOUS EXAMPLE EXCEPT
@ . THE DEFOREST DATA IS READ TO UNIT 9 IN PREPARATION FOR
@ . PARTICLE PUSHING FLUX, AND
@ . UNIT 27 (IAREA) IS REGARDED AS A RESTART FILE
@ASG,AX 10A.              . RESTART FILES
@ASG,AX 15A.
@ASG,AX 16A.
@ASG,AX 17A.
@ASG,AX 18A.
@ASG,AX 19A.
@ASG,AX 21A.
@ASG,AX 27A.
@ASG,T 9.
@ED NASCAP.DEFOR,9.
@ASG,T 10.                . SCRATCH FILES
@ASG,T 11.
@ASG,T 12.
@ASG,T 13.
@ASG,T 14.
@ASG,T 15.
@ASG,T 16.
@ASG,T 17.
@ASG,T 18.
@ASG,T 19.
@ASG,T 21.
@ASG,T 27.
@ASG,T 28.
@COPY 10A.,10.            . COPY RESTART FILES TO SCRATCH FILES
@COPY 15A.,15.
@COPY 16A.,16.
@COPY 17A.,17.
@COPY 18A.,18.
@COPY 19A.,19.
@USE 20,OBJECT            . OBJECT DEFINITION
@ASG,AX 20.
@COPY 21A.,21.
@USE 22,FLUX              . FLUX DEFINITION
@ASG,AX 22.
@ASG,T 25.
@USE 26,KEYWORD           . KEYWORD INPUT
@ASG,AX 26.
@COPY 27A.,27.
@                         . OBTAIN ABSOLUTE ELEMENT
@COPY,A NPROG.PGM,TPF$.PGM
@XQT
[RUNSTREAM] OR @ADD RUNSTREAM.
@PMD,SEB
@COPY 10.,10A.            . COPY SCRATCH FILES TO RESTART FILES
@COPY 15.,15A.
@COPY 16.,16A.
@COPY 17.,17A.
@COPY 18.,18A.
@COPY 19.,19A.
@COPY 21.,21A.
@COPY 27.,27A.
@FIN
```

Example 3. The same as example 2, except
1. The DeForest environmental data is placed on scratch file 9 for NASCAP use, and
2. The IAREA file is regarded as a restart file. (See Section 2.1.1.)

2.2 RUNSTREAM INPUT

NASCAP runstream input, which may follow the @XQT statement in the run stream, contains grid size specifications, logical unit numbers for all required files, restart (see Table 2.2) and plot flags, boundary condition and flux flags, potential solution limits and flags, time cycle limits and increment, sun direction vector and intensity, and, finally, flags and specifications for any optional plots desired.

A list of all variables read from this data set appears as Table 2.3. Unless otherwise noted, all variables are one per card, with integers in FORMAT (I5) and real numbers in FORMAT (F10.0). The remainder of this section consists of the runstream input specifications (Table 2.3), and several runstream examples.

Table 2.2. Restart Options

ICREST	IPREST	IOUTER	Description
0	0	≥ 0	New problem.
1	1	ignored	Full restart at new time step.
0	1	≥ 0	Potential restart. Start with potential calculation for final time step of previous run. IOUTER must be non-negative (see below) but is otherwise ignored.
0	1	-n	New start on a problem which has been done previously; e.g., in a different environment. Start with time step 1, t = 0, with initial charges and potentials 10^{-n} times those at end of preceeding run, then scale appropriately.
0 or 1	-n	$\gtreqless 0$	Same as IPREST = 1 above, except potentials are obtained from file n rather than file IP.

Table 2.3. Runstream Input Variables

Card No.	FORTRAN Variable Name	Description
		GRID DEFINITION
1	NX	Number of x-direction grid points. The only acceptable entry is 17.
2	NY	Number of y-direction grid points. The only acceptable entry is 17.
3	NZ	Number of z-direction grid points. Must be of the form 4n+1, with $4 \leq n \leq 8$.
4	NG	Number of nested NX x NY x NZ grids. Potential solving is done in NG grids; particle tracking is done in at most two grids.
		LOGICAL UNIT NUMBERS (LUN's)
5	IP	LUN of external file on which grid potentials will be stored (and on which potentials from previous run lie if IPREST = 1).
6	IAUN	LUN of external file on which coefficient product $(Au)^n$ values for grid points will be stored.
7	IR	LUN of external file on which conjugate gradient array r values for grid points will be stored.
8	IY	LUN of external file on which the conjugate gradient array y values for grid points will be stored.
9	IU	LUN of external file on which the conjugate gradient array u values for grid points will be stored.
10	ISPARE	LUN of the "spare" external file which will rotate values with IP, IR, IY, and IU.

Table 2.3. Continued

Card No.	FORTRAN Variable Name	Description
11	IROUS	LUN of the external file on which the ROUS charge array will be stored.
12	IPCOND	LUN of the external file onto which the PCOND array will be dumped upon run completion for restart purposes.
13	IQCOND	LUN of the external file onto which the QCOND array, ICYCS, and TIME will be dumped upon run completion for restart purposes.
14	IOBJ	LUN of external file on which OBJDEF will write the PNCND, LIST, WPCOND, and W arrays for use by OBJSPC.
15	IOBPLT	LUN of external file on which OBJDEF will write satellite block and cell definition data. IOBPLT is also a flag indicating whether or not satellite illustration plots are desired. IOBPLT > 0 implies plot material composition satellite silhouettes, non-hidden line satellite building-block plots, and hidden-line cell-by-cell plots will be plotted. IOBPLT < 0 implies do not plot satellite illustration plots, and use unit number IPLOT = IABS(IOBPLT).
16	ISAT	LUN of the object definition input file.
17	ICNOW	LUN of the external file on which the CNOW array (current surface charge) will be stored.
18	IFLUX	LUN of the flux definition input file.

Table 2.3. Continued

Card No.	FORTRAN Variable Name	Description
19	IKEYWD	LUN of the keyword input file.
20	IAREA	LUN of external file on which shadowed surface cell areas are stored. If IAREA > 0, a new sun direction vector, SUN(3), is used to make a new shadowing calculation, and the resultant areas will be stored on unit IAREA. If IAREA < 0, the shadowed areas from a previous run will be used and are presumed to be stored already on unit IABS(IAREA).
21	IPART	LUN of external file onto which PUSH will write particle trajectory data for plotting by PARPLT. Also a flag indicating whether or not particle trajectory plots (for non-tank test cases) are desired. IPART > 0 implies write particle trajectory data for particles landing on cell IOCL(1) onto file IPART, and plot these trajectories for the first time cycle.
	RESTART, OBJDEF, PLOT, BOUNDARY CONDITION AND FLUX OPTIONS	
22	ICREST	Restart flag for restarting at a new time cycle. See Table 2.2.
23	IPREST	Restart flag for potential solution. See Table 2.2.

Table 2.3. Continued

Card No.	FORTRAN Variable Name	Description
24	IOBCAL	Flag for OBJDEF call. IOBCAL = 1 implies call OBJDEF and proceed normally. IOBCAL = 0 implies OBJDEF output is already available on files IOBJ and IABS(IOBPLT). IOBCAL = -1 implies call OBJDEF (and SATPLT and HIDCEL if called for) and stop.
25	ICON	Potential contour plot flag indicating whether or not and how often potential contour plots are desired. ICON $\leq$ 0 implies no plots. ICON > 0 implies plot potential contours every ICON time cycles, starting with cycle 1.
26	ITPART	Plot flag for tank test particle trajectory plots. ITPART = 0 implies no plots. ITPART $\neq$ 0 implies plot particle trajectories.
27	ITCUR	Plot flag for tank test current contour plots. ITCUR = 0 implies no plots. ITCUR $\neq$ 0 implies plot current contours.
28	IROUSP	Plot flag for ROUS (space charge density) contour plot. IROUSP = 0 implies no plots. IROUSP $\neq$ 0 implies plot final ROUS contours.

Table 2.3. Continued

Card No.	FORTRAN Variable Name	Description
29	ICNVP	Potential convergence printer plot flag indicating whether or not and how often printer plots of convergence data are desired. ICNVP = 0 implies no plots. ICNVP > 0 implies plot convergence data every ICNVP time cycles starting with cycle 1.
30	IOUTER	Boundary condition and potential initial guess option. IOUTER = 0 implies begin with zero potential everywhere. IOUTER = 1 implies begin with 1/r potentials on outer boundary of system; zeroes in all other locations. IOUTER = 2 implies begin with 1/r potentials everywhere. IOUTER = -N (negative integer) implies multiply previous potentials and charges by 10^{-N} if ICREST = 0 and IPREST = 1. (Start at cycle 1 with scaled version of previously calculated potentials. (See Table 2.2)
31	ITYPE	Flux definition flag (must agree with first card of flux definition file). ITYPE = 1 implies test tank case. ITYPE = 2 implies isotropic Maxwellian plasma approximation. ITYPE = 3 implies particle-pushing space case (experimental data or Maxwellian ambient plasma).
		POTENTIAL CONVERGENCE PARAMETERS
32	IALG	Flag indicating which potential solution algorithm to use (0 or 1). (See Section 7.1.) Normally IALG = 1.

Table 2.3. Continued

Card No.	FORTRAN Variable Name	Description
33	MAXITR	Number of potential iterations desired. Zero is allowed; 50 is a suggested maximum. (Note possibility of potential restart.)
34	INTITR	Flag indicating that the conjugate gradient algorithm is to be reinitialized every INTITR iterations. INTITR is not normally used and should be set to a large number (e.g., 999).
35	POTEPS	Intended as an epsilon for determining quality of potential convergence. Not currently used.
		TIME CYCLE INFORMATION
36	NCYC	Number of time cycles to be run.
37	MCYC	POTENT call flag. MCYC = 0 implies POTENT will not be called to calculate new potentials; scaled potentials will be used. MCYC > 0 implies POTENT will be called every MCYC time cycles beginning with cycle 1.
38	DELTA	Length of time step in seconds for one charging cycle (time cycle).
39	DELFAC	Factor by which DELTA is multiplied at each cycle.
		SUN DEFINITION
40	SUN(3)	FORMAT (3F10.0). Vector indicating direction from center of inner grid to sun for shadowing calculation. SUN will be used to calculate new shadowed areas only if IAREA > 0. SUN need not be normalized.

Table 2.3. Continued

Card No.	FORTRAN Variable Name	Description
41	SFAC	Solar intensity relative to 1 a.u. solar constant.
		REQUESTS FOR OPTIONAL PLOTS
42	NCON, NDIR, NDIV(6)	READ 3020, NCON, NDIR, (NDIV(I),I = 1,6) 3020 FORMAT (8I5) NCON is the number of additional potential contour plot cuts desired. NDIR is the number of additional viewing directions for which the 3-D satellite illustration plots are desired. NDIV(I) is the number of extra division plots desired for the Ith view of the material composition silhouette plots (views 1 through 6 correspond to +x, -x, +y, -y, +z, and -z). If this card contains all zeroes (or is blank), no further cards will be read in. If NCON is non-zero, we read:
43a	ICNOPT(2,8)	READ 3010, ((ICNOPT(I,J),I = 1,2), J = 1, NCON) 3010 FORMAT (16I5) ICNOPT(1,J) = 1, 2, or 3 indicating the Jth cut is through fixed x, y, or z plane. ICNOPT(2,J) is an integer between 1 and NX, NY, or NZ (depending on ICNOPT(1,J), indicating the fixed value of the cut. This value is in units of the next-to-inner grid. If NDIR is non-zero, we read:

Table 2.3. Continued

Card No.	FORTRAN Variable Name	Description
43b	DIROPT(3,5)	DO 100 I = 1, NDIR READ 1030, (DIROPT(J,I), J = 1,3) 100 CONTINUE 1030 FORMAT (3F10.0) DIROPT(1,I), DIROPT(2,I), and DIROPT(3,I) form the direction-of-view vector from the satellite center to the viewer for the Ith optional view. DIROPT need not be normalized. For each non-zero entry of NDIV, we read one card:

43c	NDVAL (2,5,6)	DO 200 IVIEW = 1,6
		NDIVI = NDIV(IVIEW)
		If (NDIVI.EQ.0) go to 200
		READ 3020, IVIEW2, ((NDVAL(I,J,IVIEW2), I = 1,2), J = 1, NDIVI)
		If (IVIEW2.NE.IVIEW) RETURN 0
		3020 FORMAT (I5, 5X, 10I5)
		200 CONTINUE
		For a given view IVIEW, a card is read in with a check variable IVIEW2 (which must equal IVIEW) and NDVAL. NDVAL(1,J,IVIEW2) and NDVAL(2,J,IVIEW2) are the lower and upper limits of the Jth optional division for view IVIEW. The optional plot for this division will plot shaded surface areas for only those cells which lie within these limits (limits for the default plots are 1 to NX, 1 to NY, and 1 to NZ).

```
 1.      17          NX          1
 2.      17          NY          2
 3.      17          NZ          3
 4.       1          NG          4
 5.      10          IP          5
 6.      11          IAUN        6
 7.      12          IR          7
 8.      25          IY          8
 9.      13          IU          9
10.      14          ISPARE     10
11.      15          IHOUS      11
12.      16          IPCOND     12
13.      17          IGCOND     13
14.      18          IOBJ       14
15.     -19          IOBPLT     15
16.      20          ISAT       16
17.      21          ICNOW      17
18.      22          IFLUX      18
19.      26          IKEYWD     19
20.     -27          IAREA      20
21.       0          IPART      21
22.       1          ICHEST     22
23.       1          IPHEST     23
24.      +0          IOBCAL     24
25.       0          ICON       25
26.       0          ITPART     26
27.       0          ITCUR      27
28.       0          IHOUSP     28
29.       1          ICNVP      29
30.      -6          IOUTER     30
31.       3          ITYPE      31
32.       1          IALG       32
33.      00          MAXITR     33
34.     991          INTITR     34
35.        1.E-8     POTEPS     35
36.      03          NCYC       36
37.      02          MCYC       37
38.     .5           DELTA      38
39.        1.30      DELFAC     39
40.          1.        1.        1.     SUN DIRECTION
41.          0.      SUN INTENSITY
42.    0    0    0    0    0    0    0    0
```

Example 4 (Runstream Input). A particle-pushing space case run is to be restarted for three cycles. The object is contained in one cubic grid. No plots are requested. The potentials are to be scaled at each cycle (no CG iterations). The first cycle run will be 0.5 seconds, and the time step will increase by 30 percent each cycle. The object is in the dark.

```
 1.      17          NX          1
 2.      17          NY          2
 3.      33          NZ          3
 4.       2          NG          4
 5.      10          IP          5
 6.      11          IAUN        6
 7.      12          IR          7
 8.      25          IT          8
 9.      13          IU          9
10.      14          ISPARE     10
11.      15          IROUS      11
12.      16          IPCOND     12
13.      17          IQCOND     13
14.      18          IOBJ       14
15.     +19          IOBPLT     15
16.      20          ISAT       16
17.      21          ICNOW      17
18.      22          IFLUX      18
19.      26          IRETWD     19
20.     +27          IAREA      20
21.      28          IPART      21
22.       0          ICREST     22
23.       1          IPRLST     23
24.     +0           IOBCAL     24
25.       1          ICON       25
26.       0          ITPART     26
27.       0          ITCUR      27
28.       0          IROUSP     28
29.       1          ICNVP      29
30.      -6          IOUTER     30
31.       2          ITYPE      31
32.       1          IALG       32
33.      25          MAXITR     33
34.     991          INTITR     34
35.        1.E-8     POTEPS     35
36.      01          NCYC       36
37.      01          NCYC       37
38.     .00005       DELTA      38
39.        1.30      DELFAC     39
40.          1.        1.         1.     SUN DIRECTION
41.          1.      SUN INTENSITY
42.       0    0    0    0    0    0    0    0
```

Example 5 (Runstream Input). A space case in the Maxwell probe approximation is to be run with two full grids, starting from time zero. The object has been defined previously, and a set of potentials exists. The area calculation will be performed for the sun shining from the (111) grid direction. Object plots and potential contour plots will be made. One cycle will be run for 5×10^{-5} seconds, including 25 CG potential iterations.

```
 1.      17          NX          1
 2.      17          NY          2
 3.      33          NZ          3
 4.       3          NG          4
 5.      10          IP          5
 6.      11          IAUN        6
 7.      12          IR          7
 8.      25          IY          8
 9.      13          IU          9
10.      14          ISPARE     10
11.      15          IHOUS      11
12.      16          IPCOND     12
13.      17          IQCOND     13
14.      18          IOBJ       14
15.     +19          IOBPLT     15
16.      20          ISAT       16
17.      21          ICNOW      17
18.      22          IFLUX      18
19.      26          IKEYWD     19
20.     -27          IAREA      20
21.      28          IPART      21
22.       0          ICHEST     22
23.       0          IPHEST     23
24.      +1          IOBCAL     24
25.       1          ICON       25
26.       1          ITPART     26
27.       1          ITCUR      27
28.       0          IHOUSP     28
29.       1          ICNVP      29
30.      -0          IOUTER     30
31.       1          ITTPE      31
32.       1          IALG       32
33.      25          MAXITR     33
34.     991          INTITR     34
35.        1.E-8     PUTLPS     35
36.      01          NCYC       36
37.      01          MCYC       37
38.     .00005       DELTA      38
39.        1.30      DELFAC     39
40.          1.        1.        1.      SUN DIRECTION
41.          0.      SUN INTENSITY
42.      0    0    0    0    0    0    0    0
```

Example 6 (Runstream Input). A test tank case is to be run in three full grids. This is a new problem. The object will be defined and object plots made. Tank particle trajectory plots and current density contour plots are requested. One cycle will be run for 5×10^{-5} seconds, with 25 potential iterations.

2.3 FLUX DEFINITION INPUT

The first card of the IFLUX file must contain the word 'TYPE' in columns 1-4 and 1, 2, or 3 in column 10. The value must agree with card 31 of the runstream input. The types are:

1 - Test tank, electron beam case

2 - Isotropic Maxwellian space case

3 - Particle-pushing space case

Subsequent cards differ for each case.

<u>Type 1</u> - Test tank with electron beam source

Card 2	- IBMCAL (I4) Normally 0; set to 1 for stop after initial beam calibration.
Card 3	- Z-location of beam calibration plane in grid units (F10.1).
Card 4	- Beam size (X and Y) at the calibration plane (meters) (2F10.2).
Card 5	- Beam energy (eV) (F10.1).
Card 6	- Initial electron velocity in code units (E10.2).
Card 7	- Gun location in <u>outer</u> grid units (3F10.1).
Card 8	- Sample plane (in grid units) (F10.1).
Card 9	- Total beam current (amperes) (F10.1).
Cards 10-45	- Current density calibration values (11F4.1).

All beam information is calibrated using the maximum value of the beam size from card 4. The current density array contains the current density profile as a function of (R,θ) for 36 evenly spaced angles and 11 evenly spaced radial values Each card read contains the 11 radial values at a single angular value.

$$r_i = \frac{(i-1)}{10} \times \text{beam size (card 4)}$$

$$\theta_i = \frac{(i-1)}{36} \times 2\pi$$

The central value is repeated on each card. The values are read in arbitrary units and the code will normalize the total beam current to the input value. Card 8, the sample plane location should be on or behind the target; it is used for terminating particle trajectories. (See Figures 2.1, 2.2.)

Type 2 - Maxwellian probe approximation

All cards are FORMAT (F10.0, A6). Accepted literals are MKS and CGS for plasma density, EV, JOULES, KEV, and KELVIN for plasma temperature. The first density/energy refers to electrons and the last to protons. The literal END (optional) is also accepted, and terminates the flux definition.

Type 3 - Flux determined by reverse trajectory particle tracking

Card 2 contains one of the two literals (A6) MAXWEL or DEFOR. Following 'MAXWEL' input is as in Type 2, (q.v.), except an END card is required. Following 'DEFOR', cards are required giving IUNIT, RHOUR, IDAY (I5/F10.0/I5). The data contained in the ELT NASCAP.DEFOR must have been copied onto file IUNIT.

Table 2.4 lists the input RHOUR, IDAY for which data from ATS-5 is in the DEFOR file. The particle spectra for these times are described in Appendix A of Reference 1. Any other data may be used if it is prepared in the following fashion. The data must consist of 63 card images with the following format:

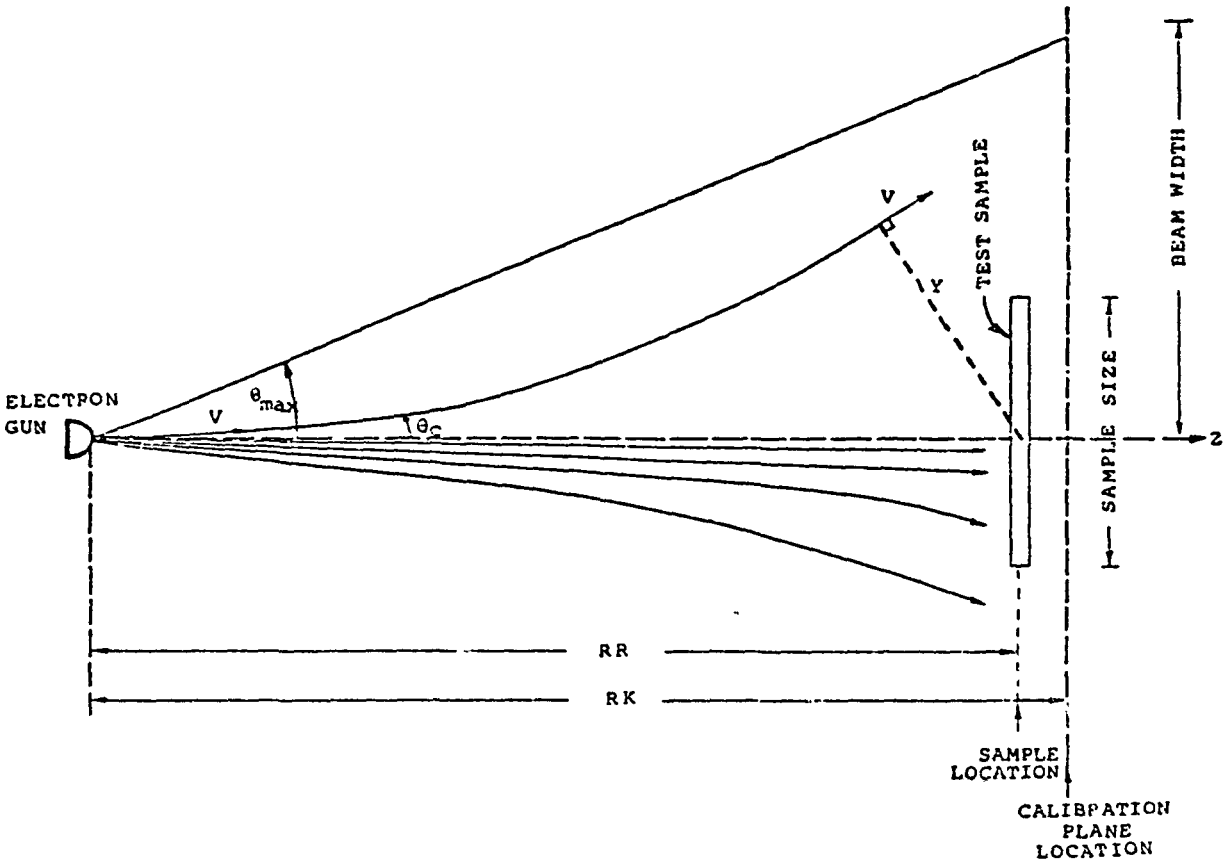


Figure 2.1. Geometry of the test tank configuration.

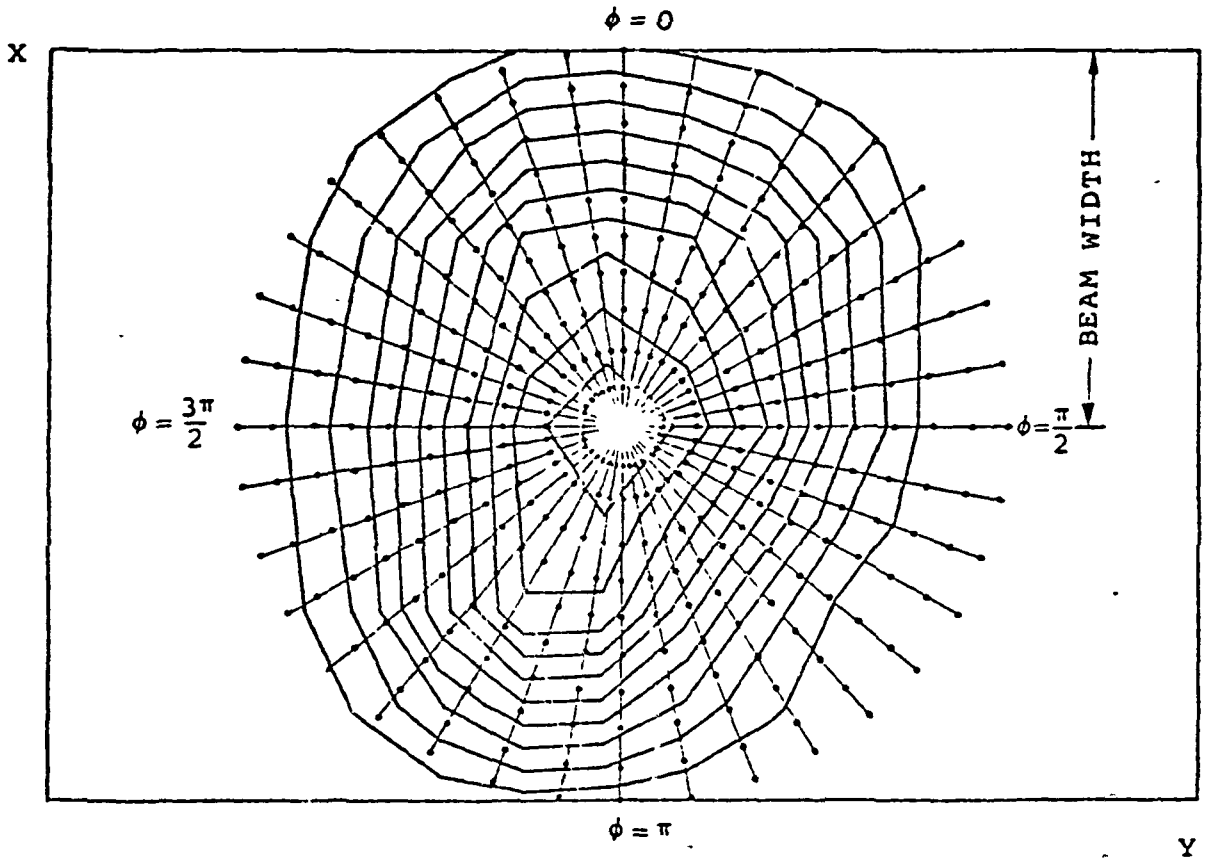


Figure 2.2. Specification of electron gun characteristics for the test tank case. Electron fluxes at the sample plane for an uncharged environment are to be specified at the solid points.

Table 2.4. Hours and Days for ATS-5 Flux Data Contained in File Element NASCAP.DEFOR.

Date	RHOUR	IDAY
3/14/71	5.999	73
	7.000	73
	7.501	73
	8.001	73
	8.502	73
	9.998	73
12/3/70	1.997	337
	3.999	337
	6.001	337
	7.002	337
	7.997	337
	12.001	337
3/18/70	8.998	77
	9.999	77
	10.818	77
	11.205	77
	12.001	77
	17.006	77

5 FORMAT (I2, 1X, 4F12.2, 2F8.3, I4, F4.3)

The Read list is

```
READ (IUNIT,5) K,(FDEF(J,K), J=1,5), RHOUR, IDAY, AVMIN
K = card number (1-63) and energy bin number.
FDEF(1,K) = parallel electron flux in eV/(cm^2 sec sr eV).
FDEF(2,K) = parallel proton flux in eV/(cm^2 sec sr eV).
FDEF(3,K) = perpendicular electron flux in eV/
            (cm^2 sec sr eV).
FDEF(4,K) = perpendicular proton flux in eV/
            (cm^2 sec sr eV).
FDEF(5,K) = lower bound on energy bin (eV).
RHOUR     = checked against requested hour.
IDAY      = checked against requested day.
AVMIN     = not used.
```

Missing flux data is indicated with a 0. FSPACE assumes that there is no flux above 50 keV and that data on cards past 28 are for energies above 1000 eV. The flux for a velocity $\underset{\sim}{V}$ is assumed to be

$$f(V) = \frac{|\underset{\sim}{V}\cdot\underset{\sim}{V}_s|}{|\underset{\sim}{V}|\ |\underset{\sim}{V}_s|} f_{parallel} + \left(1 - \frac{|\underset{\sim}{V}\cdot\underset{\sim}{V}_s|}{|\underset{\sim}{V}|\ |\underset{\sim}{V}_s|}\right) f_{perpendicular}$$

where $\underset{\sim}{V}_s$ is a direction vector, whose FORTRAN name is STV (see below).

Subsequent cards contain

NSPEC	(I5)	Number of species
NENG	(I5)	Number of energies
NTHET	(I5)	Number of polar angles
NPHI	(I5)	Number of azimuthal angles
NSTP	(I5)	Maximum number of steps per particle

RMASS(1), CHARGE(1)	(2F10.16)	
.		Mass (kg), charge (C)
.		
.		
RMASS(NSPEC), CHARGE(NSPEC)		
VCODE	(F10.6)	Initial code velocity
STV(3)	(3F10.0)	Vector characterizing flux anisotropy

The present code requires NSPEC = 2, with species 1 being electrons and species 2 protons. The final card, STV, may be omitted, in which case the flux is assumed isotropic.

```
TYPE      2
 1.00     CGS
 1.0      CGS
 10.00    KEV
10.0      KEV
```

Example 7 (Flux Definition). Defines a neutral 10 keV plasma for use in the Maxwell probe operating mode.

```
TYPE      3
MAXWELL
 1.00     CGS
 1.0      CGS
 10.00    KEV
 10.00    KEV
          END
    2                 NSPEC
    5                 NENG
    5                 NTHET
    5                 NPHI
  100                 NSTP
   9.1E-31  -1.6E-19          MASS, CHARGE
  16.7E-28   1.6E-19          MASS, CHARGE
  0.3                 VCODE
```

Example 8 (Flux Definition). Defines a neutral 10 keV Maxwellian plasma for use in the reverse trajectory particle pushing mode.

```
 1.        TYPE      3
 2.        DEFOR
 3.            9
 4.        9.998
 5.           73
 6.            2                NSPEC
 7.            5                NENG
 8.            5                NTHET
 9.            1                NPHI
10.          200                NSTP
11.        9.1E-31  -1.6E-19          MASS, CHARGE
12.       16.7E-28   1.6E-19          MASS, CHARGE
13.        0.3                  VCODE
```

Example 9 (Flux Definition). Takes flux from DeForest environmental data for hour 9.998 of day 73. The data is read from LUN 9.

```
 1.        TYPE      3
 2.        MAXWELL
 3.         0.53     CGS
 4.         0.6      CGS
 5.         4.114    KEV
 6.        0.43      KEV
 7.                  END
 8.            2                NSPEC
 9.           05                NENG
10.            5                NTHET
11.            1                NPHI
12.          100                NSTP
13.        9.1E-31  -1.6E-19          MASS, CHARGE
14.       16.7E-28   1.6E-19          MASS, CHARGE
15.        0.3                  VCODE
```

Example 10 (Flux Definition). Defines a non-neutral, non-equilibrium Maxwellian plasma for use by the reverse trajectory particle pushing mode.

```
 1.        TYPE     1
 2.           0
 3.              21.0
 4.               .30          .30
 5.           2000.0
 6.            .50E00
 7.               9.0          9.0          9.0
 8.              21.0
 9.           8.40E-7
10.        10.0 10.0  9.0  8.3  7.6  6.6  4.7  3.2  1.5  0.5  0.0
11.        10.0  9.8  9.0  8.0  7.4  6.5  4.5  2.9  1.4  0.5  0.0
12.        10.0  9.7  9.0  8.0  6.9  5.6  4.4  2.8  1.4  0.5  0.0
13.        10.0  9.6  8.9  7.6  6.0  5.6  4.4  2.6  1.3  0.5  0.0
14.        10.0  9.6  8.8  7.5  6.3  5.3  3.9  2.3  0.9  0.5  0.0
15.        10.0  9.7  8.7  7.4  6.0  4.5  3.0  1.7  0.5  0.0  0.0
16.        10.0  9.8  8.6  7.5  5.7  3.9  2.7  1.0  0.5  0.0  0.0
17.        10.0  9.9  8.7  7.3  5.5  3.4  1.8  0.5  0.5  0.0  0.0
18.        10.0 10.0  8.9  7.4  5.5  3.3  1.7  0.3  0.5  0.0  0.0
19.        10.0  9.9  8.7  7.2  5.4  3.2  1.5  0.1  0.5  0.0  0.0
20.        10.0  9.8  8.5  6.8  4.9  2.7  1.1  0.5  0.0  0.0  0.0
21.        10.0  9.8  8.4  6.7  4.6  2.6  1.0  0.5  0.0  0.0  0.0
22.        10.0  9.8  8.5  6.7  4.7  2.7  1.1  0.5  0.0  0.0  0.0
23.        10.0  9.9  8.5  6.9  5.0  3.1  1.4  0.1  0.5  0.0  0.0
24.        10.0  9.9  8.6  7.1  5.2  3.5  1.7  0.6  0.5  0.0  0.0
25.        10.0 10.0  8.7  7.4  5.6  3.9  2.6  1.1  0.1  0.5  0.0
26.        10.0 10.0  9.0  7.7  6.3  4.8  3.2  1.8  0.4  0.5  0.0
27.        10.0 10.0  9.2  8.3  7.5  5.8  4.0  2.5  0.7  0.5  0.0
28.        10.0 10.0  9.6  9.0  8.5  7.5  5.5  3.5  1.5  0.5  0.0
29.        10.0 10.0  9.9  9.0  8.7  6.6  5.8  4.0  2.1  0.5  0.0
30.        10.0 10.0  9.6  9.0  8.9  6.9  5.0  3.8  1.9  0.5  0.0
31.        10.0 10.0  9.4  9.0  8.7  6.6  5.4  3.5  1.6  0.5  0.0
32.        10.0 10.0  9.4  9.0  7.6  6.6  4.7  3.0  1.4  0.5  0.0
33.        10.0 10.0  9.4  8.7  7.6  5.5  3.6  2.2  1.0  0.5  0.0
34.        10.0 10.0  9.3  8.5  6.6  5.2  3.0  1.6  0.5  0.0  0.0
35.        10.0 10.0  9.3  8.1  6.2  4.4  2.5  1.2  0.2  0.5  0.0
36.        10.0 10.0  9.4  8.2  6.3  4.3  2.4  1.1  0.1  0.5  0.0
37.        10.0 10.0  9.5  8.3  6.2  4.2  2.4  1.1  0.1  0.5  0.0
38.        10.0 10.0  9.4  8.1  6.2  4.3  2.5  1.2  0.2  0.5  0.0
39.        10.0 10.0  9.3  8.1  6.2  4.4  2.7  1.5  0.5  0.0  0.0
40.        10.0 10.0  9.2  8.2  6.5  4.8  3.4  2.0  0.8  0.5  0.0
41.        10.0 10.0  9.1  8.1  6.8  5.5  4.0  2.4  1.1  0.5  0.0
42.        10.0 10.0  9.1  8.2  7.3  6.3  4.5  2.7  1.5  0.5  0.0
43.        10.0 10.0  9.2  8.3  7.4  6.0  5.0  3.1  1.4  0.5  0.0
44.        10.0 10.0  9.1  8.4  7.5  6.5  4.7  3.4  1.5  0.5  0.0
45.        10.0 10.0  9.0  8.4  7.6  6.5  4.6  3.3  1.5  0.0  0.0
```

Example 11 (Flux Definition). Defines flux in the tank test mode with a 2 keV beam.

2.4 KEYWORD INPUT

Additional input to NASCAP is contained in file IKEYWD. This file must be present and have proper attributes, though it may contain no card images. The format is a 'keyword' beginning in column 1, of which the first six characters are significant, and data (if any) beginning in column 21. With the exceptions noted below, cards may appear in any order.

	Keyword	Data	Data Format
1.	COMMENT	none	
2.	END	none	
3.	SURFACE CELL	ICELL	(I10)
4.	LONGTIMESTEP	none	
5.	SHEATH	none	
6.	NOSHEATH	none	
7.	SCALE	none	
8.	NOSCALE	none	
9.	DSCALE	none	
10.	TANKSIZE	IL, IR	(2I5)
11.	BFIELD	B(3)	(3F10.0)
12.	DIPOLE	P(3), R(3)	(6F10.0)
13.	CIJ	I, J, C	(2I5, F10.0)
14.	BIAS	I, VBIAS	(I10, F10.0)
15.	FIXP	I, VFIX	(I10, F10.0)

EXPLANATIONS

1. Ignore card.

2. Ignore subsequent cards.

3. Print detailed information for surface cell numbered ICELL. If particle plots are made, they are for the lowest numbered such cell.

4. Evoke the LONGTIMESTEP algorithm. This is useful for an object whose monopole potential is fully developed but is being differentially charged.

5.-6. Treat space charge and fluxes due to emitted low energy electrons to first order. The default is NOSHEATH.

7.-8. The potential may be scaled from the previous result according to the total charge prior to the conjugate gradient calculation. The default is SCALE if conductor 1 is floating and NOSCALE if conductor 1 is fixed.

9. Potential to be scaled according to [total charge - (sum of charge on fixed potential conductors)].

10. The Z-dimension of the outer grid may be truncated from the left and/or right. (The outer grid must include the next inner grid.)

11. Constant magnetic field in Webers/m^2.

12. Magnetic dipole with moment $\vec{P}$(A - m^2) at location $\vec{R}$ (grid units).

13. Capacitance C (farads) between conductors I and J. This is to be used for conductors which are glued together or are separated by a thin insulating layer; capacitance between disjoint conductors is handled implicitly.

14. Conductor I to be biased at VBIAS (volts) relative to conductor 1, which is considered spacecraft ground. Biasing must be done in order, beginning with conductor 2.

15. Potential of conductor I to be fixed at VFIX. Spacecraft ground may be fixed.

```
SURFACE CELL                55
CIJ                     1    2  347.E-12
SURFACE CELL               216
SURFACE CELL               298
SURFACE CELL               312
SURFACE CELL               436
NOSCALE
FIXP                         1   -575.
SURFACE CELL                 4
SURFACE CELL                92
SURFACE CELL                95
SURFACE CELL                78
SURFACE CELL                31
SURFACE CELL               103
SURFACE CELL                15
SURFACE CELL                 4
TANKSIZE                04  14
END
BFIELD                0.        .000052   -.000019
END
BIAS                         2   70.
END
CIJ                     2    3 .00005
CIJ                     1    3 .009
BIAS                         2   10.
FIXP                         3   33.
END
```

Example 12 (Keyword Input). Several surface cells are chosen for output. A capacitance of 347 pf is placed between conductors 1 and 2. Potential scaling is suppressed. Conductor 1 is fixed at -575 volts. The outermost grid is truncated at subscripts Z = 4 and Z = 14. Remaining cards are ignored (although in correct format).

```
 1.    SURFACE CELL          55
 2.    DSCALE
 3.    FIXP                   1   00.
 4.    SURFACE CELL           9
 5.    SURFACE CELL          92
 6.    LONGTIMESTEP
 7.    NOSHEATH
 8.    TANKSIZE        08    27
 9.    BFIELD        0.          .000052   -.000019
10.    END
```

Example 13 (Keyword Input). Three surface cells are chosen for output. The DSCALE potential scaling option is invoked. Conductor 1 is grounded. The LONGTIMESTEP option is invoked and the SHEATH option is suppressed. The outer grid is truncated at subscripts Z = 8 and Z = 27. A constant magnetic field is present.

3. OUTPUT

3.1 GENERAL CONSIDERATIONS

NASCAP provides a great deal of output, both printed and graphical, to aid the user in following the progress of the simulation. To a large extent NASCAP output is self-explanatory. In this chapter we provide further description to help the user understand and anticipate NASCAP output.

3.2 PRINTED OUTPUT

NASCAP printed output includes:

1. Runstream input echo (self-explanatory)
2. Object definition output (Section 6.3)
3. Shadowing calculation output (Section 3.2.1)
4. Flux definition output (self-explanatory)
5. Keyword input echo and summary (Section 3.2.2)
6. Time cycle output
   a. CHARGE segment output (Section 3.2.3)
   b. POTENT segment output (Section 3.2.4)
7. Final values of potential array (Section 3.2.5)

In addition, self-explanatory messages are printed at various points to help the user monitor the progress of the code and determine whether the desired actions are being taken.

3.2.1 Shadowing Calculation Printout

Subroutine HIDCEL prints out a variety of diagnostic information when HIDCEL is called for a shadowing calculation. (When called for satellite illustration, HIDCEL prints only the final number of shielded Al polygons, NAl.)

HIDCEL first prints a list of the initial unshielded A1 polygons: For each polygon, the following data is printed:

IA1: Index of this A1 polygon.

IA1T: Index of surface cell which generated this A1 polygon.

NVM1: Number of vertices of this A1 polygon.

AREA2(IA1T): Unshielded area of this A1 polygon.

Next, the number of initial A1 polygons, NA1, the number of initial A2 polygons, NA2, and a print flag, IP, are printed.

Next, the set of final A1 polygons and their final (shielded) areas are printed. The surface cell index IA1T of each polygon's parent cell is also printed. If a polygon occurs which contributes to the area of a surface cell which an earlier polygon (or polygons) has contributed to, a message to this effect is printed.

A list of the final fractional areas (= original unshielded area/final shielded area) for each surface cell is printed, along with the original unshielded and final shielded areas themselves.

Finally, the set of shielded A1 polygons in 2-D is explicitly listed by printing the complete vertex set for each polygon (including the duplicate first vertex at the end of the list).

3.2.2 Keyword Input Echo and Summary

Each card read by the keyword input routine, INKEYW, is echoed. In addition, many of the keywords elicit an immediate response verifying the requested action. The message "DECODE ERROR" results from an improper data format,

which results in program termination. An unrecognized keyword also results in termination.

Following the input echo, a summary is presented. The surface cells specified for flux I/O are listed. The code units of charge and capacitance are given. ($V = Q/4\pi R$, where V is in volts and Q and R are in code units.) The matrix of capacitances between conductors is printed. The values of the LONGTIMESTEP, SHEATH, and potential scaling options are given. Truncation of the outer grid is noted. The constant magnetic field and any magnetic dipoles present are listed.

3.2.3 CHARGE Segment Output

The CHARGE segment printed output is as follows:

1. Following a page feed, the cycle number, time total charge, and potentials and charges on conductors are printed.
2. For the test tank case, some of the internal variables are printed, followed by the array CURENT(3,NX,NY), the incident current at the sample plane.
3. Detailed information is printed for each surface cell specified in the keyword input. This includes the internal code defining the surface cell, its location, outward normal, and composition, the mean potential on the surface and the mean normal electric field in the thin dielectric, the various incident and emitted flux components, and the net flux. The potentials, fields, and fluxes are those at the beginning time of the time step.
4. The net charging current to the object is printed.

5. If the LONGTIMESTEP option has been invoked, items 3 and 4 are repeated for scaled potentials at the advance time.

6. If the SHEATH option has been invoked, the corrected fluxes are printed for each of the selected surface cells.

7. The updated time is printed, followed by the CNOW array (the charge on each surface cell).

3.2.4 Potential Solution Printout

QSUM, the sum of all charges in the system is printed out initially, as are the PCOND and QCOND arrays. NC, the number of conductors in this problem is printed. Next, MBIAS, the number of biased conductors (1 if none are biased) and the VBIAS array containing the amounts of voltage bias are printed.

Next, several variables to be used by OBJSPC are printed: SWPCIJ, SSCIJ, SWPSSC, arrays CIJSUM, SWPCND, and ROUSCN.

Finally, we enter the potential solution proper, and the initial value of RDOTR is printed. The potential iteration loop prints out a repeated series of convergence related data including: iteration number, QCOND(1), SWPCND(1), AUNC(1), PCOND(1), RCOND(1), UCOND(1), the PCOND and QCOND arrays, UDOTAU ($u^n \cdot (Au)^n$), ALPHA, RDOTR and RDOTRS ($r^{n+1} \cdot r^{n+1}$ and $r^n \cdot r^n$), BETA, C and CS (c^{n+1} and c^n), RTDOT ($\tilde{r} \cdot \tilde{r}$, the monotonic residual), and, finally, UDOTU ($u^n \cdot u^n$).

Upon completion of the potential solution and call to QCONCP, the final PCOND and QCOND arrays are again printed.

If convergence printer plot data was called for by ICNVP > 0, printer plots follow: the first plots the log of RDOTR versus iteration number; the second plots either (algorithm 0) the log of UDOTAU versus iteration number, or (algorithm 1) the monotonic residual RTDOT against iteration number; the third plots the potential on conductor one versus iteration number.

3.2.5 Potential Array Printout

Final potentials are the last output for any run in which POTENT has been called. The successive blocks of numbers may be regarded as X-Y cuts through a potential map. Successive grids of data are printed, beginning with the innermost grid. For the innermost grid, zeroes indicate the object interior. For outer grids, the next inner grid appears as a block of zeroes.

3.3 PLOT OUTPUT FROM NASCAP

NASCAP generates a wide variety of diagnostic plots. Any of these may be requested or suppressed via user-defined input flags in the main input file.

3.3.1 Satellite Illustration Plots

Several types of plots illustrating the satellite are created when IOBPLT > 0. These plots serve not only as report quality output, but also as diagnostic output for the programmer himself. Defining a complex satellite in three-dimensions, complete with a variety of surface materials is a task prone to errors, especially for those unfamiliar with the code. The satellite illustration plots are an important early-on indication of whether or not the satellite as imagined has been properly communicated to the code.

The first of these plots are the material composition silhouettes. From each of the six possible on-axis directions, a view of the satellite is plotted showing each surface cell and the material it is comprised of via up to fifteen different area shadings. In a complex satellite involving some inward-facing surfaces, surface cells hidden by another surface will not be shown by the six default views. However, the user may request additional plots for any or all of the six viewing directions specifying a given subset (or subsets) of the possible x, y, or z values such that only those surface cells falling within the specified range will be plotted. In this way a set of silhouettes may be generated which illustrates the material composition of all surfaces of the satellite.

Two types of three-dimensional perspective plots aid in picturing the satellite: (1) non-hidden-line perspective plots of each of the satellite "blocks" as defined by the user

in input file ISAT; and (2) hidden-line perspective plots of the satellite showing all surface cell boundaries. The first plot echoes back the user's definition of the satellite form, and the second illustrates the three-dimensional shape and code resolution of the satellite in a clear fashion. Each of these plots is plotted for each of three different default viewing directions, viz. (.5,.8,.5), (-.5,.8,.5), and (.2,-.5,.5). The user may also specify up to five additional viewing directions.

An additional hidden-line cell-by-cell perspective plot will be plotted as a diagnostic feature when a surface cell shadowing calculation is requested (IAREA > 0). In this case the direction-of-view is defined by the SUN input vector.

3.3.2 Potential Contour Plots

Potential contour plots will be generated when ICON > 0. Contours may be plotted along any cut across the inner two grids; however, the default action is to plot contours along the x-y, x-z, and y-z planes through the center of the grid. Up to eight additional cuts may be requested by user input. The projection of the satellite perimeter is also plotted with the contours. (Calling for potential contours for a one-grid problem will result in abnormal termination.)

3.3.3 ROUS Contour Plots

Contours of the ROUS charge array as of the final cycle will be plotted when IROUS > 0. Contour plot cuts are the same as the default cuts for potential contours: the x-y, x-z, and y-z planes passing through the center of the grid. However, since ROUS is defined only for the inner grid, only one grid is plotted.

The projection of the satellite perimeter is again plotted with the contours.

3.3.4 Particle Trajectory Plots (Non-Tank Test Case)

When IPART > 0, particle trajectories across the inner two grids will be plotted for the first time cycle. Three trajectory projections (x-y, x-z, and y-z planes) will be plotted for each of the two particle species (electrons and protons). Only trajectory data for those particles which hit the lowest numbered cell specified in the KEYWORD input (or cell 1 if none have been specified) are plotted.

The projection of the satellite perimeter is also plotted with the trajectories.

3.3.5 Particle Trajectory Plot (Tank Test)

When ITPART ≠ 0, particle trajectories projected onto the x-z plane will be plotted.

The projection of the satellite perimeter will also be plotted.

3.3.6 Current Contour Plot (Tank Test)

When ITCUR ≠ 0, current contours along the x-y plane through the center of the grid will be plotted.

The projection of the satellite perimeter will also be plotted.

4. SAMPLE RUN

As a crude illustration of how NASCAP may be used, a short sample run is presented. This run begins a simulation of a teflon coated sphere with nominal diameter 0.9 meters in a neutral 14 keV plasma of density 1 cm^{-3}. The flux definition, keyword and object definition inputs are shown in Figures 4.1 through 4.3.

The printed run output appears in pages 57 to 91. Prior to the first cycle appear the runstream input echo, the object definition output (Section 6.3), the shadowing calculation output (Section 3.2.1), the flux definition echo, and the keyword input echo and summary.

Cycle 1 begins on page 68. The negligible initial charges and potentials result from the $1/4\pi r$ boundary condition and initial potential guess. The problem is slightly asymmetric because it is not possible to locate a sphere of diameter 3 mesh units exactly at the center of the computational space. For this case, the net flux to the sphere is ∿7 percent of the incident electron flux.

The potential calculation may be traced through the printout on pages 69 through 74, and is summarized by the plots on pages 75 through 77. The non-monotonic residual (RDOTR) and the decreasing reconstructed residual (RTDOT, although the title is UDOTAU) illustrate the rapid convergence during the early iterations, followed by slower convergence in the later cycles. Though the solution is continuing to improve after the twenty-five requested iterations, the plot of the conductor potential (third plot) indicates that further iterations are not worthwhile.

The second cycle (page 78) begins at 0.001 seconds with a potential of -11 volts. This is sufficient to

```
ALUMINUM
1.        0.010     -1.       13.       0.97      .3        260.      1
240.      1.73      1.36      40.         4.E-05 14.        15.       16
17.       18.       19.       20.       21.       22.       23.       24.
TEFLON
2.000     0.0100          1.E-14    10.     3.        0.3       -1.       0.
  2.2     16.7      1.4       70.         2.00E-05    14.         15.
17.       18.       19.       20.       21.       22.       23.       24.
OSPHERE
CENTER        0     0     0
DIAMETER      3
SIDE          1
MATERIAL  TEFLON
ENDOBJ
MESH SIZE   0.3
ENDSAT
```

Figure 4.1. Object definition input for sample run.

```
TYPE      2
 1.00      CGS
 1.0       CGS
 14.00     KEV
14.0       KEV
```

Figure 4.2. Flux definition input for sample run.

```
SURFACE CELL        15
SURFACE CELL         4
END
```

Figure 4.3. Keyword input for sample run.

noticeably reduce the net charging current. At the end of the simulation (0.0024 seconds) the sphere is at a potential of 25 volts.

Finally, the potential array at the end of the simulation is printed. The graphical output from this run (pages 92 to 95) shows the quasisphere as viewed from the sun direction and three sets of potential contours calculated after the cycle 1 conjugate gradient iteration process. On each potential contour plot the minimum and maximum potentials in volts (ZMIN, ZMAX) in the plane, and the interval between contours (ΔZ) are indicated.

```
NX = 17
NY = 17
NZ = 17
NG =  2

IP = 10
IAUN = 11
IR = 12
IY = 25
IU = 13
ISPARL = 14
IROUS = 15
IPCOND = 16
IWCOND = 17

IOBJ = 18
IOBPLT = -19
ISAT = 20

ICNOW = 21
IFLUX = 22
IKEYWD = 26
IAREA =  27
IPART =  28

ICALST =  0
IPRLST =  0
IOBCAL =  1
ICON =  1
ICNVP =  1
IOUTER =  2
ITYPE =  3
ITPART =  0
ITCUR =  0
IROUSP =  0

IF IOBCAL = 0, OBJDEF NOT CALLED, XMESH, ETC. READ FROM FILE ABS(IOBPLT)

IALG =  1

MAXITR = 25
INTITR = **
POTEPS =  1.0000-08

NCYC =  2
MCYC =  10
DELTA =  1.0000-03
```

```
DELFAC =  1.4000+00

UNNORMALIZED SUN DIRECTION VECTOR =     1.000    1.000    1.000
NORMALIZED SUN DIRECTION VECTOR =       .577     .577     .577
RELATIVE SUN INTENSITY =  0.0000

NO. OF ADDITIONAL CONTOUR PLOT CUTS =     0

NO. OF ADDITIONAL 3-D PLOT VIEWS =     0

NO. OF ADDITIONAL MATERIAL PLOT VIEWS =     0    0    0    0    0    0
```

```
ALUMIN              MATERIAL PROPERTIES
            1.00+00    1.00-02   -1.00+00   1.30+01   9.70-01   3.00-01   2.60+02   1.30+00   2.40+02   1.73+00
            1.36+00    4.00+01    4.00-05   1.40+01   1.50+01   1.60+01   1.70+01   1.80+01   1.90+01   2.00+01

TEFLON              MATERIAL PROPERTIES
            2.00+00    1.00-02   1.00-14    1.00+01   3.00+00   3.00-01  -1.00+00   0.00      2.20+00   1.67+01
            1.40+00    7.00+01   2.00-05    1.40+01   1.50+01   1.60+01   1.70+01   1.80+01   1.90+01   2.00+01

QSPHER

   DEFINING Q-SPHERE
         CENTER =   9   9   9
         DIAMETER =   3     SIDE =   1
         MATERIAL = TEFLON

   OCTAGON DEFINED
         AXIS = (   9   9   9) TO (  10   9   9)
         WIDTH =    3          SIDE =    1

   OCTAGON DEFINED
         AXIS = (   9   9   9) TO (   9  10   9)
         WIDTH =    3          SIDE =    1

   OCTAGON DEFINED
         AXIS = (   9   9   9) TO (   9   9  10)
         WIDTH =    3          SIDE =    1

MESH 5      0.3

ENDSAT
CALLING TRNGLS
```

SURFACE CELL LIST

CELL NO.	CODE	CONDUCTOR	IX	IY	IZ	NORMAL			MATERIAL
1	011010107742	1	8	8	8	-1	-1	-1	TEFLON
2	011010117402	1	8	8	9	-1	-1	0	TEFLON
3	011010127542	1	8	8	10	-1	-1	1	TEFLON
4	011011106302	1	8	9	8	-1	0	-1	TEFLON
5	011011116002	1	8	9	9	-1	0	0	TEFLON
6	011011126102	1	8	9	10	-1	0	1	TEFLON
7	011012106742	1	8	10	8	-1	1	-1	TEFLON
8	011012116402	1	8	10	9	-1	1	0	TEFLON
9	011012126542	1	8	10	10	-1	1	1	TEFLON
10	011110101702	1	9	8	8	0	-1	-1	TEFLON
11	011110111402	1	9	8	9	0	-1	0	TEFLON
12	011110121502	1	9	8	10	0	-1	1	TEFLON
13	011111100302	1	9	9	8	0	0	-1	TEFLON
14	011111120102	1	9	9	10	0	0	1	TEFLON
15	011112100702	1	9	10	8	0	1	-1	TEFLON
16	011112110402	1	9	10	9	0	1	0	TEFLON
17	011112120502	1	9	10	10	0	1	1	TEFLON
18	011210103742	1	10	8	8	1	-1	-1	TEFLON
19	011210113402	1	10	8	9	1	-1	0	TEFLON
20	011210123542	1	10	8	10	1	-1	1	TEFLON
21	011211102302	1	10	9	8	1	0	-1	TEFLON
22	011211112002	1	10	9	9	1	0	0	TEFLON
23	011211122102	1	10	9	10	1	0	1	TEFLON
24	011212102742	1	10	10	8	1	1	-1	TEFLON
25	011212112402	1	10	10	9	1	1	0	TEFLON
26	011212122542	1	10	10	10	1	1	1	TEFLON

PREPROCESSING OF MATERIAL PROPERTIES

MATERIAL 1: ALUMIN

	PROPERTY	INPUT VALUE	CODE VALUE
1	DIELECTRIC CONSTANT	1.00+00 (NONE)	1.00+00 (NONE)
2	THICKNESS	1.00-02 METERS	3.33-02 MESH
3	CONDUCTIVITY	-1.00+00 MHO/M	-1.00+00 MHO/M
4	ATOMIC NUMBER	1.30+01 (NONE)	1.30+01 (NONE)
5	DELTA MAX >COEFF	9.70-01 (NONE)	7.21+00 (NONE)
6	E-MAX >DEPTH**-1	3.00-01 KEV	1.73-02 ANG-01
7	RANGE	2.60+02 ANG.	3.38+02 ANG.
8	EXPONENT > RANGE	1.30+00 (NONE)	4.15+02 ANG.
9	RANGE > EXPONENT	2.40+02 ANG.	1.30+00 (NONE)
10	EXPONENT	1.73+00 (NONE)	1.73+00 (NONE)
11	YIELD FOR 1KEV PROTONS	1.36+00 (NONE)	1.36+00 (NONE)
12	MAX DE/DX FOR PROTONS	4.00+01 KEV	4.00+01 KEV
13	PHOTOCURRENT	4.00-05 A/M**2	4.00-05 A/M**2
14		1.40+01	1.40+01
15		1.50+01	1.50+01
16		1.60+01	1.60+01
17		1.70+01	1.70+01
18		1.80+01	1.80+01
19		1.90+01	1.90+01
20		2.00+01	2.00+01

MATERIAL 2: TEFLON

	PROPERTY	INPUT VALUE	CODE VALUE
1	DIELECTRIC CONSTANT	2.00+00 (NONE)	2.00+00 (NONE)
2	THICKNESS	1.00-02 METERS	3.33-02 MESH
3	CONDUCTIVITY	1.00-14 MHO/M	1.00-14 MHO/M
4	ATOMIC NUMBER	1.00+01 (NONE)	1.00+01 (NONE)
5	DELTA MAX >COEFF	3.00+00 (NONE)	1.96+01 (NONE)
6	E-MAX >DEPTH**-1	3.00-01 KEV	2.99-02 ANG-01
7	RANGE	-1.00+00 ANG.	4.58+02 ANG.
8	EXPONENT > RANGE	0.00 (NONE)	0.00 ANG.
9	RANGE > EXPONENT	2.20+00 ANG.	1.69+00 (NONE)
10	EXPONENT	1.67+01 (NONE)	1.00+00 (NONE)
11	YIELD FOR 1KEV PROTONS	1.40+00 (NONE)	1.40+00 (NONE)
12	MAX DE/DX FOR PROTONS	7.00+01 KEV	7.00+01 KEV
13	PHOTOCURRENT	2.00-05 A/M**2	2.00-05 A/M**2
14		1.40+01	1.40+01
15		1.50+01	1.50+01
16		1.60+01	1.60+01
17		1.70+01	1.70+01
18		1.80+01	1.80+01
19		1.90+01	1.90+01
20		2.00+01	2.00+01

CALLING SHIPTS
CALLING SPECEL
CALLING SPCWGT

ELEMENT TABLE

I	J	K	ENTRY
8	8	8	0000000056704
8	8	9	0000000056301
8	8	10	0000000056304
8	9	8	0000000075201
8	9	10	0000000035201
8	10	8	0000000052704
8	10	9	0000000052301
8	10	10	0000000052304
9	8	8	0000000671601
9	8	10	0000000631001
9	10	8	0000000271601
9	10	10	0000000231001
10	8	8	0000000016704
10	8	9	0000000016301
10	8	10	0000000016304
10	9	8	0000000071201
10	9	10	0000000031201
10	10	8	0000000012704
10	10	9	0000000012301
10	10	10	0000000012304

CALLING SPCPTS
CALLING SPCWGT

```
29 SURFACE POINTS, INCLUDING      0 MULTICONDUCTOR POINTS.

32 SPECIAL POINTS


26 VOLUME CELLS NUMBERED BY NUMLTD.
POLYGON   1 FOR CELL    9 WITH  3 VERTICES HAS INITIAL AREA =  2.8834-01
POLYGON   2 FOR CELL   14 WITH  4 VERTICES HAS INITIAL AREA =  5.7835-01
POLYGON   3 FOR CELL   16 WITH  4 VERTICES HAS INITIAL AREA =  5.7835-01
POLYGON   4 FOR CELL   17 WITH  4 VERTICES HAS INITIAL AREA =  1.1587+00
POLYGON   5 FOR CELL   20 WITH  3 VERTICES HAS INITIAL AREA =  2.8834-01
POLYGON   6 FOR CELL   22 WITH  4 VERTICES HAS INITIAL AREA =  5.7835-01
POLYGON   7 FOR CELL   23 WITH  4 VERTICES HAS INITIAL AREA =  1.1587+00
POLYGON   8 FOR CELL   24 WITH  3 VERTICES HAS INITIAL AREA =  2.8834-01
POLYGON   9 FOR CELL   25 WITH  4 VERTICES HAS INITIAL AREA =  1.1587+00
POLYGON  10 FOR CELL   26 WITH  3 VERTICES HAS INITIAL AREA =  8.7004-01
```

```
NA1 =    10     NA2 =    12     IP =     0

FINAL NA1 =    10
    IA1 =    1  NV =  4  IAIT =    9  AREA1(IAIT) =  2.8834-01
    IA1 =    2  NV =  5  IAIT =   14  AREA1(IAIT) =  5.7835-01
    IA1 =    3  NV =  5  IAIT =   16  AREA1(IAIT) =  5.7835-01
    IA1 =    4  NV =  5  IAIT =   17  AREA1(IAIT) =  1.1587+00
    IA1 =    5  NV =  4  IAIT =   20  AREA1(IAIT) =  2.8834-01
    IA1 =    6  NV =  5  IAIT =   22  AREA1(IAIT) =  5.7835-01
    IA1 =    7  NV =  5  IAIT =   23  AREA1(IAIT) =  1.1587+00
    IA1 =    8  NV =  4  IAIT =   24  AREA1(IAIT) =  2.8834-01
    IA1 =    9  NV =  5  IAIT =   25  AREA1(IAIT) =  1.1587+00
    IA1 =   10  NV =  4  IAIT =   26  AREA1(IAIT) =  8.7004-01
CELL    9 WITH INITIAL PROJECTED AREA =  2.8834-01 HAS SHIELDED AREA =  2.8834-01 FOR AN AREA FRACTION =  1.0000+00
CELL   14 WITH INITIAL PROJECTED AREA =  5.7835-01 HAS SHIELDED AREA =  5.7835-01 FOR AN AREA FRACTION =  1.0000+00
CELL   16 WITH INITIAL PROJECTED AREA =  5.7835-01 HAS SHIELDED AREA =  5.7835-01 FOR AN AREA FRACTION =  1.0000+00
CELL   17 WITH INITIAL PROJECTED AREA =  1.1587+00 HAS SHIELDED AREA =  1.1587+00 FOR AN AREA FRACTION =  1.0000+00
CELL   20 WITH INITIAL PROJECTED AREA =  2.8834-01 HAS SHIELDED AREA =  2.8834-01 FOR AN AREA FRACTION =  1.0000+00
CELL   22 WITH INITIAL PROJECTED AREA =  5.7835-01 HAS SHIELDED AREA =  5.7835-01 FOR AN AREA FRACTION =  1.0000+00
CELL   23 WITH INITIAL PROJECTED AREA =  1.1587+00 HAS SHIELDED AREA =  1.1587+00 FOR AN AREA FRACTION =  1.0000+00
CELL   24 WITH INITIAL PROJECTED AREA =  2.8834-01 HAS SHIELDED AREA =  2.8834-01 FOR AN AREA FRACTION =  1.0000+00
CELL   25 WITH INITIAL PROJECTED AREA =  1.1587+00 HAS SHIELDED AREA =  1.1587+00 FOR AN AREA FRACTION =  1.0000+00
CELL   26 WITH INITIAL PROJECTED AREA =  8.7004-01 HAS SHIELDED AREA =  8.7004-01 FOR AN AREA FRACTION =  1.0000+00
IA1 =    1     IAIT =    9     NV =  4
 1    .70833361    1.22686987    2   1.41503045     .81696825    3   1.41666722     .00000012    4    .70833361   1.22686987
IA1 =    2     IAIT =   14     NV =  5
 1    .00000000    1.63488096    2    .70833361    1.22686987    3    .00000000     .81836655    4   -.70833361   1.22686987
 5    .00000000    1.63488096
IA1 =    3     IAIT =   16     NV =  5
 1   1.41584937   -.81744035    2   1.41666722     .00000012    3    .70874351    -.40919315    4    .70833361  -1.22686975
 5   1.41584937   -.81744035
IA1 =    4     IAIT =   17     NV =  5
 1   1.41666722    .00000012    2    .70874351    -.40919315    3    .00000000     .81836655    4    .70833361   1.22686987
 5   1.41666722    .00000012
IA1 =    5     IAIT =   20     NV =  4
 1  -1.41666722    .00000012    2  -1.41503045     .81696825    3   -.70833360    1.22686987    4  -1.41666722    .00000012
IA1 =    6     IAIT =   22     NV =  5
 1  -1.41584937   -.81744035    2  -1.41666722     .00000012    3   -.70874351    -.40919315    4   -.70833361  -1.22686975
 5  -1.41584937   -.81744035
IA1 =    7     IAIT =   23     NV =  5
 1  -1.41666722    .00000012    2   -.70874351    -.40919315    3    .00000000     .81836655    4   -.70833361   1.22686987
 5  -1.41666722    .00000012
IA1 =    8     IAIT =   24     NV =  4
 1   -.70833361  -1.22686975    2    .70833361   -1.22686975    3    .00000000   -1.63393638    4   -.70833361  -1.22686975
IA1 =    9     IAIT =   25     NV =  5
 1   -.70833361  -1.22686975    2   -.70874351    -.40919315    3    .70874351    -.40919315    4    .70833361  -1.22686975
 5   -.70833361  -1.22686975
IA1 =   10     IAIT =   26     NV =  4
 1   -.70874351    -.40919315    2    .70874351    -.40919315    3    .00000000     .81836655    4   -.70874351    -.40919315
```

```
FLUX DEFINITION
      TYPE      4
            ELECTRON TEMPERATURE =      1.40+04 ELECTRON VOLTS
            ELECTRON DENSITY =          1.00+06 METER**(-3)
            ION TEMPERATURE =           1.40+04 ELECTRON VOLTS
            ION DENSITY =               1.00+06 METER**(-3)
 POTENTIALS TO BE SET BY SETALL TO     1.00+00/(4*PI*R)
*** CYCLE LOOP FROM CYCLE    1 TO CYCLE    2
```


ORIGINAL PAGE IS
OF POOR QUALITY

```
          KEYWORD INPUT
SURFACE CELL                    15                          0
                    CELL    15 INFORMATION TO BE PRINTED.
SURFACE CELL                     4
                    CELL     4 INFORMATION TO BE PRINTED.
END
```

```
KEYWORD INPUT SUMMARY

 2 SURFACE CELLS SPECIFIED FOR I/O:
                    4   15

        THE CODE UNIT OF CHARGE IS     2.66-12 COULOMBS.
        THE CODE UNIT OF CAPACITANCE IS     2.66-12FARADS.

CIJ:
          0.00       0.00       0.00       0.00       0.00       0.00       0.00
          0.00       0.00       0.00       0.00       0.00       0.00       0.00
          0.00       0.00       0.00       0.00       0.00       0.00       0.00
          0.00       0.00       0.00       0.00       0.00       0.00       0.00
          0.00       0.00       0.00       0.00       0.00       0.00       0.00
          0.00       0.00       0.00       0.00       0.00       0.00       0.00
          0.00       0.00       0.00       0.00       0.00       0.00       0.00

CIJSUM:     0.00       0.00       0.00       0.00       0.00       0.00       0.00

        LONGTIMESTEP OPTION =*NOFIX *

        POTENTIAL SCALING OPTION =*SCALE *

        SHEATH OPTION =*NO     *

        FULL OUTER GRID USED

                  CONSTANT MAGNETIC FIELD =(    .00       .00       .00    ) W/M**2.

   NO MAGNETIC DIPOLES

        NC DETERMINED BY GETNC TO BE  1
```

```
CYCLE    1          TIME =    0.000    SECONDS.

QSUM =  1.0000+00
PCOND =  4.7689-02   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
QCOND =  0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
-----------------------------------------------------------------------------

  SURFACE CELL NO.    4                                  CODE =        011011106302
                                                         LOCATION =     8  9  8
                                                         NORMAL =      -1  0 -1
                                                         MATERIAL =   TEFLON
                              POTENTIAL =   6.792-02 VOLTS
                              FIELD =  -2.023+00 VOLTS/METER
   FLUXES IN A/M**2
        INCIDENT ELECTRONS                          3.17-06
             RESULTING BACKSCATTER                  8.60-07
             RESULTING SECONDARIES                  1.30-06
        INCIDENT PROTONS                            7.39-08
             RESULTING SECONDARIES                  7.08-07
        PHOTOCURRENT                                0.00
                                                  ----------
       NET FLUX .                                  -2.21-07
-----------------------------------------------------------------------------

  SURFACE CELL NO.   15                                  CODE =        011112100702
                                                         LOCATION =     9 10  8
                                                         NORMAL =       0  1 -1
                                                         MATERIAL =   TEFLON
                              POTENTIAL =   4.440-02 VOLTS
                              FIELD =   3.292-01 VOLTS/METER
   FLUXES IN A/M**2
        INCIDENT ELECTRONS                          3.17-06
             RESULTING BACKSCATTER                  8.60-07
             RESULTING SECONDARIES                  1.31-06
        INCIDENT PROTONS                            7.39-08
             RESULTING SECONDARIES                  7.12-07
        PHOTOCURRENT                                0.00
                                                  ----------
       NET FLUX                                    -2.12-07

          NET CHARGING CURRENT =  -2.16+05 (CODE UNITS/SEC.).

     CHARGE PART OF CYCLE    1 COMPLETE.
    TIME HAS BEEN UPDATED TO      1.000-03 SECONDS.

CNOW ARRAY

  -6.7515+00   -1.0601+01   -6.2992+00   -1.0603+01   -7.4991+00   -1.0162+01   -6.2992+00   -1.0162+01   -6.1378+00   -1.0603+01
  -7.4991+00   -1.0162+01   -7.4991+00   -7.0496+00   -1.0162+01   -7.0496+00   -9.9116+00   -6.2992+00   -1.0162+01   -6.1378+00
  -1.0162+01   -7.0496+00   -9.9116+00   -6.1378+00   -9.9116+00   -6.0521+00
```

```
USUM = -2.1626+02
PCOND = -1.0313+01   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
QCOND = -6.5903-13   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
IN POTENT, NC =      1
NBIAS =    1     VBIAS =  0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
SWPCIJ =  1.7939+03  SSCIJ =  0.0000     SWPSSC =  1.7939+03
CIJSUM =  0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
SWPCND = -1.7939+03   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
RDUSCN = -6.5903-13   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
AFTER UNSETQ RDOTR =  1.3530+06

  ITER =    1QC=-6.5903-13  SWPC=-1.7939+03  AUNC=-4.8828-04  PC=-1.0313+01  RC= 4.8828-04  UC = 4.8828-04
PCOND =   -1.0313+01   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
QCOND =   -6.5903-13   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
AFTER LOOP COPROD UDOTAU =  1.0212+08

ALPHA =  1.3250-02

AFTER RUPDAT RDOTR =  6.0440+03  RDOTRS = 1.3530+06

BETA =  4.4670-03

C =  1.0045+00  CS =  3.0000+00  R-TILDA DOT R-TILDA =  1.3530+06  UDOTU =  1.3530+06
  ITER =    2QC=-6.5903-13  SWPC=-1.7939+03  AUNC= 2.9717+03  PC=-1.0313+01  RC=-3.9374+01  UC =-3.9374+01
PCOND =   -1.0313+01   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
QCOND =   -6.5903-13   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
AFTER LOOP COPROD UDOTAU =  3.0466+06

ALPHA =  1.9839-03

AFTER RUPDAT RDOTR =  1.4522+04  RDOTRS = 6.0440+03

BETA =  2.4027+00

C =  3.4134+00  CS =  1.0045+00  R-TILDA DOT R-TILDA =  6.0171+03  UDOTU =  6.0709+03
  ITER =    3QC=-6.5903-13  SWPC=-1.7939+03  AUNC=-7.0715+04  PC=-1.0391+01  RC= 1.0091+02  UC = 6.3083+00
PCOND =   -1.0391+01   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
QCOND =   -6.5903-13   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
AFTER LOOP COPROD UDOTAU =  3.0375+06

ALPHA =  4.7808-03

AFTER RUPDAT RDOTR =  6.2148+02  RDOTRS = 1.4522+04

BETA =  4.2797-02

C =  1.1461+00  CS =  3.4134+00  R-TILDA DOT R-TILDA =  4.2543+03  UDOTU =  4.9569+04
  ITER =    4QC=-6.5903-13  SWPC=-1.7939+03  AUNC= 2.1514+05  PC=-1.0361+01  RC=-1.9408+00  UC =-1.6708+00
PCOND =   -1.0361+01   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
QCOND =   -6.5903-13   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
AFTER LOOP COPROD UDOTAU =  2.9531+03
```

```
ALPHA =  2.1045-01

AFTER RUPDAT RDOTR =  2.6947+03  RDOTRS = 6.2148+02

BETA =  9.3359+00

C =  5.9693+00  CS =  1.1461+00  R-TILDA DOT R-TILDA =  5.4226+02  UDOTU =  7.1226+02
  ITER =    SGC=-6.5903-13  SWPC=-1.7939+03  AUNC=-7.3434+00  PC=-1.0713+01  RC=-3.9534-01  UC =-7.6399+00
PCOND =   -1.0713+01   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
QCOND =   -6.5903-13   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
AFTER LOOP COPROD UDOTAU =  8.6178+04

ALPHA =  3.1269-02

AFTER RUPDAT RDOTR =  5.5205+02  RDOTRS = 2.6947+03

BETA =  2.0486-01

C =  2.2229+00  CS =  5.9693+00  R-TILDA DOT R-TILDA =  4.5142+02  UDOTU =  1.6085+04
  ITER =    6GC=-6.5903-13  SWPC=-1.7939+03  AUNC=-1.0381+01  PC=-1.0952+01  RC=-7.0743-02  UC =-1.6359+00
PCOND =   -1.0952+01   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
QCOND =   -6.5903-13   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
AFTER LOOP COPROD UDOTAU =  2.8717+04

ALPHA =  1.9224-02

AFTER RUPDAT RDOTR =  2.4482+02  RDOTRS = 5.5205+02

BETA =  4.4348-01

C =  1.9858+00  CS =  2.2229+00  R-TILDA DOT R-TILDA =  2.4834+02  UDOTU =  1.2271+03
  ITER =    7GC=-6.5903-13  SWPC=-1.7939+03  AUNC=-6.7956+02  PC=-1.0983+01  RC= 1.2993+01  UC = 1.2267+01
PCOND =   -1.0983+01   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
QCOND =   -6.5903-13   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
AFTER LOOP COPROD UDOTAU =  3.0594+05

ALPHA =  8.0022-04

AFTER RUPDAT RDOTR =  1.1788+02  RDOTRS = 2.4482+02

BETA =  4.8148-01

C =  1.9561+00  CS =  1.9858+00  R-TILDA DOT R-TILDA =  1.2328+02  UDOTU =  4.8616+02
  ITER =    8GC=-6.5903-13  SWPC=-1.7939+03  AUNC= 2.3314+04  PC=-1.0973+01  RC=-5.6635+00  UC = 2.4300-01
PCOND =   -1.0973+01   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
QCOND =   -6.5903-13   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
AFTER LOOP COPROD UDOTAU =  4.8345+02

ALPHA =  2.4357-01

AFTER RUPDAT RDOTR =  6.1728+02  RDOTRS = 1.1788+02

BETA =  5.2367+00
```

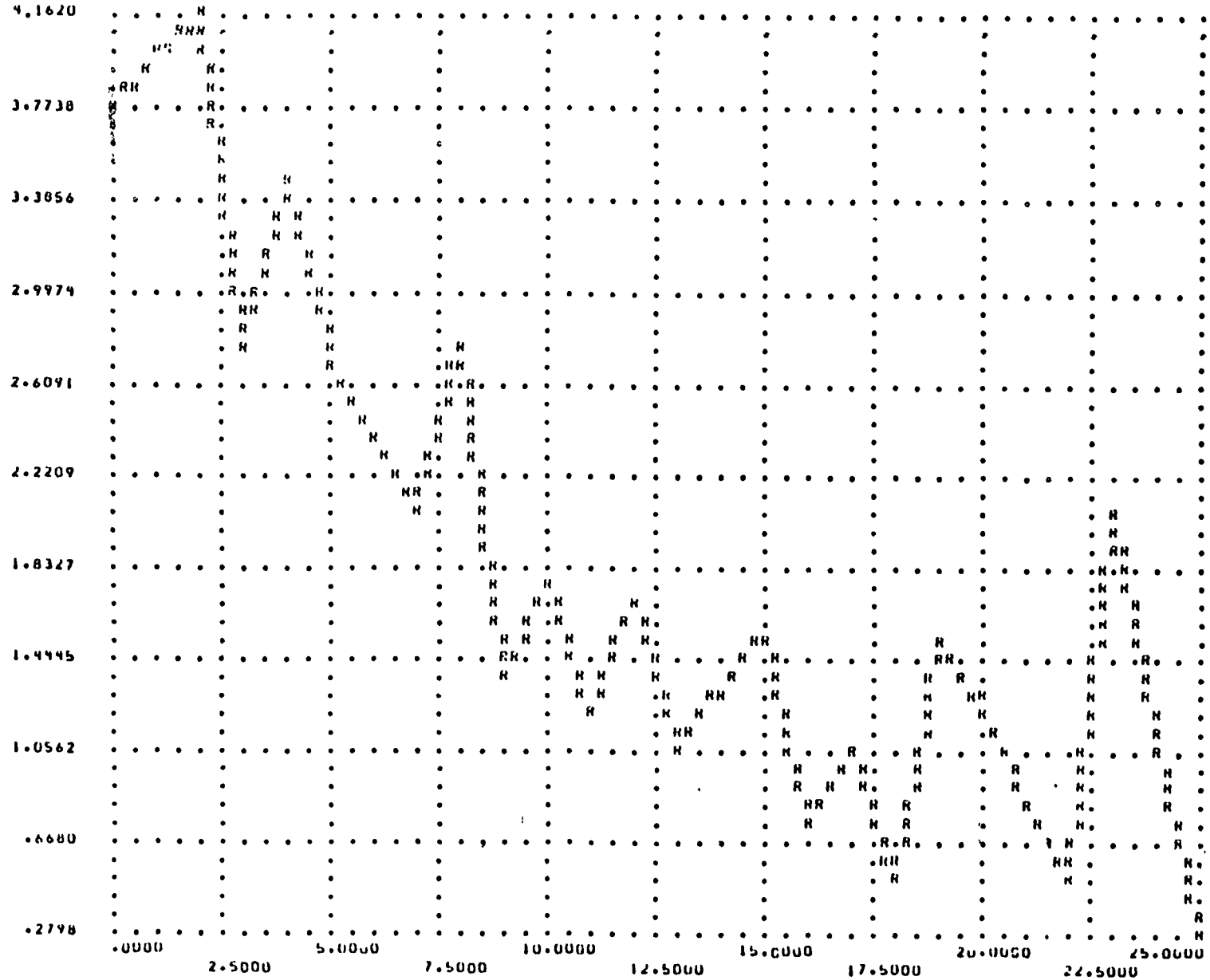
```
C =  1.1244+01  CS =  1.9561+00  R-TILDA DOT R-TILDA =  6.0259+01  UDOTU =  2.3056+02
  ITER =    9QC=-6.5903-13  SWPC=-1.7939+03  AUNC=-2.3601+01  PC=-1.0914+01  RC= 8.5104-02  UC = 1.3576+00
PCOND =   -1.0914+01   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
QCOND =   -6.5903-13   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
AFTER LOOP COPROD UDOTAU =  2.9416+04

ALPHA =  2.0984-02

AFTER RUPDAT RDOTR =  2.2415+01  RDOTRS = 6.1728+02

BETA =  3.6313-02

C =  1.4083+00  CS =  1.1244+01  R-TILDA DOT R-TILDA =  5.4899+01  UDOTU =  6.9403+03
  ITER =   10QC=-6.5903-13  SWPC=-1.7939+03  AUNC= 1.1164+01  PC=-1.0886+01  RC=-1.4916-01  UC =-9.9656-02
PCOND =   -1.0886+01   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
QCOND =   -6.5903-13   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
AFTER LOOP COPROD UDOTAU =  3.4813+01

ALPHA =  6.4388-01

AFTER RUPDAT RDOTR =  5.3719+01  RDOTRS = 2.2415+01

BETA =  2.3966+00

C =  4.3750+00  CS =  1.4083+00  R-TILDA DOT R-TILDA =  1.5916+01  UDOTU =  3.1567+01
  ITER =   11QC=-6.5903-13  SWPC=-1.7939+03  AUNC=-1.0082+01  PC=-1.0950+01  RC= 6.3426+00  UC = 6.1033+00
PCOND =   -1.0950+01   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
QCOND =   -6.5903-13   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
AFTER LOOP COPROD UDOTAU =  7.7661+04

ALPHA =  6.9154-04

AFTER RUPDAT RDOTR =  1.5561+01  RDOTRS = 5.3719+01

BETA =  2.8967-01

C =  2.2673+00  CS =  4.3750+00  R-TILDA DOT R-TILDA =  1.2278+01  UDOTU =  2.3502+02
  ITER =   12QC=-6.5903-13  SWPC=-1.7939+03  AUNC= 1.1792+04  PC=-1.0946+01  RC=-1.8119+00  UC =-4.3953-02
PCOND =   -1.0946+01   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
QCOND =   -6.5903-13   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
AFTER LOOP COPROD UDOTAU =  6.5166+01

ALPHA =  2.3871-01

AFTER RUPDAT RDOTR =  5.1820+01  RDOTRS = 1.5561+01

BETA =  3.3302+00

C =  8.5505+00  CS =  2.2673+00  R-TILDA DOT R-TILDA =  6.8629+00  UDOTU =  3.5260+01
  ITER =   13QC=-6.5903-13  SWPC=-1.7939+03  AUNC=-7.7998+00  PC=-1.0956+01  RC= 5.0009-02  UC =-9.6360-02
PCOND =   -1.0956+01   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
QCOND =   -6.5903-13   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
AFTER LOOP COPROD UDOTAU =  1.7775+03
```

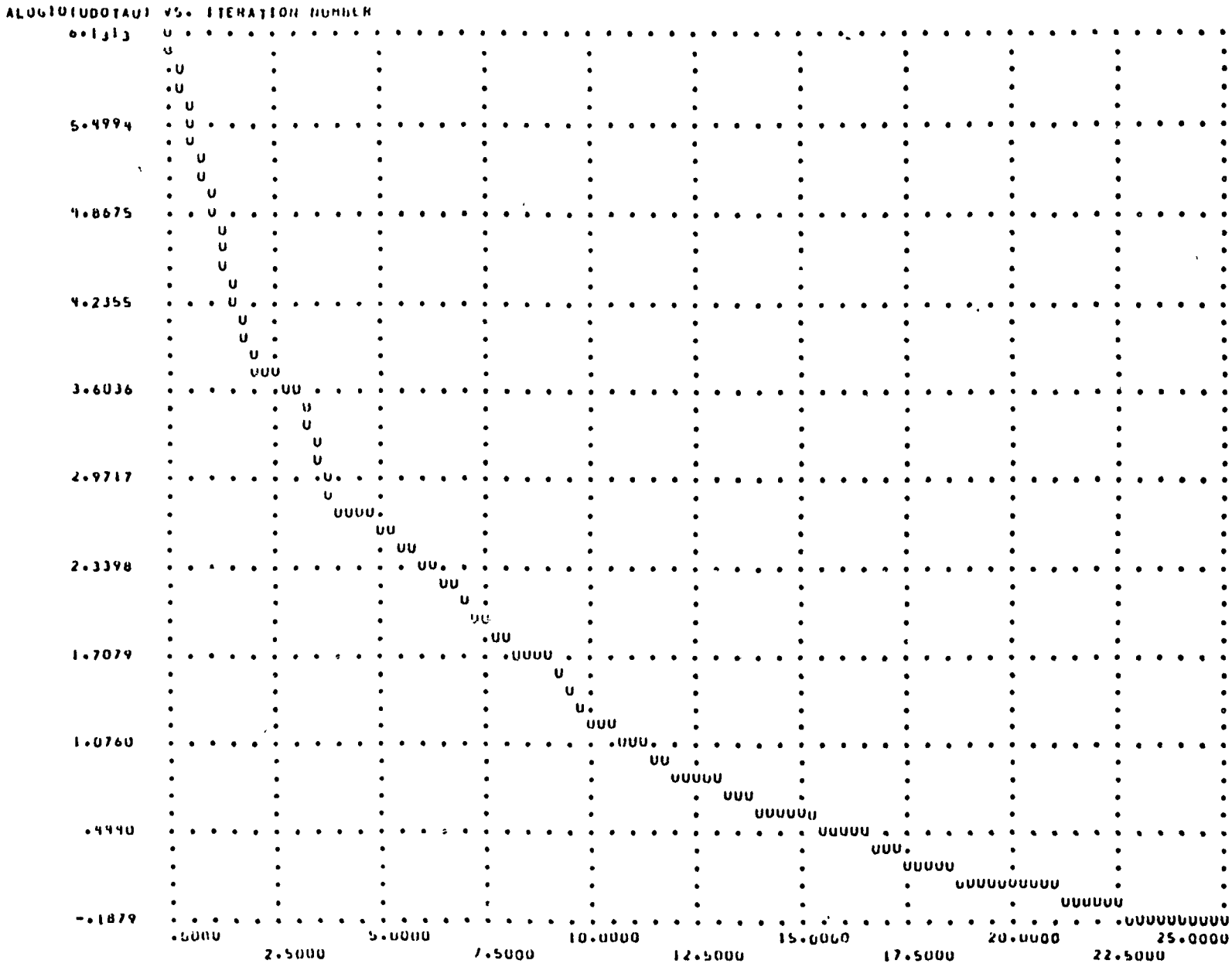
```
ALPHA =  2.9153-02

AFTER RUPDAT RDOTR =  1.1121+01  RDOTRS = 5.1820+01

BETA =  2.1461-01

C =  2.8350+00  CS =  8.5505+00  R-TILDA DOT R-TILDA =  6.0603+00  UDOTU =  4.4307+02
  ITER =   14WC=-6.5903-13  SWPC=-1.7939+03  AUNC= 5.5101-01  PC=-1.0959+01  RC= 3.3943-02  UC = 1.3266-02
PCOND =   -1.0959+01   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
QCOND =   -6.5903-13   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
AFTER LOOP COPROD UDOTAU =  3.4306+01

ALPHA =  3.2341-01

AFTER RUPDAT RDOTR =  2.1115+01  RDOTRS = 1.1121+01

BETA =  1.6988+00

C =  6.3830+00  CS =  2.8350+00  R-TILDA DOT R-TILDA =  3.9226+00  UDOTU =  3.1527+01
  ITER =   15WC=-6.5903-13  SWPC=-1.7939+03  AUNC=-8.1319+00  PC=-1.0955+01  RC= 2.6639+00  UC = 2.6891+00
PCOND =   -1.0955+01   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
QCOND =   -6.5903-13   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
AFTER LOOP COPROD UDOTAU =  1.4300+04

ALPHA =  1.4766-03

AFTER RUPDAT RDOTR =  3.4874+01  RDOTRS = 2.1115+01

BETA =  1.6517+00

C =  1.1543+01  CS =  6.3830+00  R-TILDA DOT R-TILDA =  3.3080+00  UDOTU =  1.3478+02
  ITER =   16WC=-6.5903-13  SWPC=-1.7939+03  AUNC= 4.9623+03  PC=-1.0951+01  RC=-4.6633+00  UC =-2.2183-01
PCOND =   -1.0951+01   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
QCOND =   -6.5903-13   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
AFTER LOOP COPROD UDOTAU =  3.6446+03

ALPHA =  9.0711-03

AFTER RUPDAT RDOTR =  5.2357+00  RDOTRS = 3.4874+01

BETA =  1.5013-01

C =  2.7329+00  CS =  1.1543+01  R-TILDA DOT R-TILDA =  3.0214+00  UDOTU =  4.0255+02
  ITER =   17WC=-6.5903-13  SWPC=-1.7939+03  AUNC=-5.1834+02  PC=-1.0953+01  RC= 3.8588-02  UC = 5.2[illegible]-03
PCOND =   -1.0953+01   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
QCOND =   -6.5903-13   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
AFTER LOOP COPROD UDOTAU =  1.0729+01

ALPHA =  9.7905-01

AFTER RUPDAT RDOTR =  1.1415+01  RDOTRS = 5.2357+00

BETA =  2.1804+00
```

```
C =  6.9589+00  CS =  2.7329+03  R-TILDA 001 R-TILDA =  1.9158+00  UDOTU =  1.4309+01
  ITER =   18QC=-6.5903-13  SWPC=-1.7939+03  AUNC= 7.0842-02  PC=-1.0950+01  RC= 8.1797-04  UC = 1.2339-02
PCOND =   -1.0950+01   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
QCOND =   -6.5903-13   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
AFTER LOOP COPROD UDOTAU =  6.0329+02

ALPHA =  1.8922-02

AFTER RUPDAT RDOTR =  3.3392+00  RDOTRS = 1.1415+01

BETA =  2.9252-01

C =  3.0356+00  CS =  6.9589+00  R-TILDA 001 R-TILDA =  1.6405+00  UDOTU =  7.9441+01
  ITER =   19QC=-6.5903-13  SWPC=-1.7939+03  AUNC= 2.9025+01  PC=-1.0950+01  RC=-5.4840-01  UC =-5.4479-01
PCOND =   -1.0950+01   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
QCOND =   -6.5903-13   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
AFTER LOOP COPROD UDOTAU =  5.6369+02

ALPHA =  5.9238-03

AFTER RUPDAT RDOTR =  3.2427+01  RDOTRS = 3.3392+00

BETA =  9.7110+00

C =  3.0479+01  CS =  3.0356+00  R-TILDA 001 R-TILDA =  1.1000+00  UDOTU =  1.0137+01
  ITER =   20QC=-6.5903-13  SWPC=-1.7939+03  AUNC= 9.8881+02  PC=-1.0953+01  RC= 5.3091+00  UC = 1.8643-02
PCOND =   -1.0953+01   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
QCOND =   -6.5903-13   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
AFTER LOOP COPROD UDOTAU =  2.0705+03

ALPHA =  1.5662-02

AFTER RUPDAT RDOTR =  1.8331+01  RDOTRS = 3.2427+01

BETA =  5.6530-01

C =  1.8230+01  CS =  3.0479+01  R-TILDA 001 R-TILDA =  1.0640+00  UDOTU =  9.8835+02
  ITER =   21QC=-6.5903-13  SWPC=-1.7939+03  AUNC= 3.4622+02  PC=-1.0953+01  RC=-1.1317-01  UC =-1.0263-01
PCOND =   -1.0953+01   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
QCOND =   -6.5903-13   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
AFTER LOOP COPROD UDOTAU =  3.8117+02

ALPHA =  4.8091-02

AFTER RUPDAT RDOTR =  6.9986+00  RDOTRS = 1.8331+01

BETA =  3.8178-01

C =  7.9598+00  CS =  1.8230+01  R-TILDA 001 R-TILDA =  1.0056+00  UDOTU =  3.3417+02
  ITER =   22QC=-6.5903-13  SWPC=-1.7939+03  AUNC=-2.5134+00  PC=-1.0958+01  RC= 7.6985-03  UC =-3.1485-02
PCOND =   -1.0958+01   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
QCOND =   -6.5903-13   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
AFTER LOOP COPROD UDOTAU =  2.2919+02
```

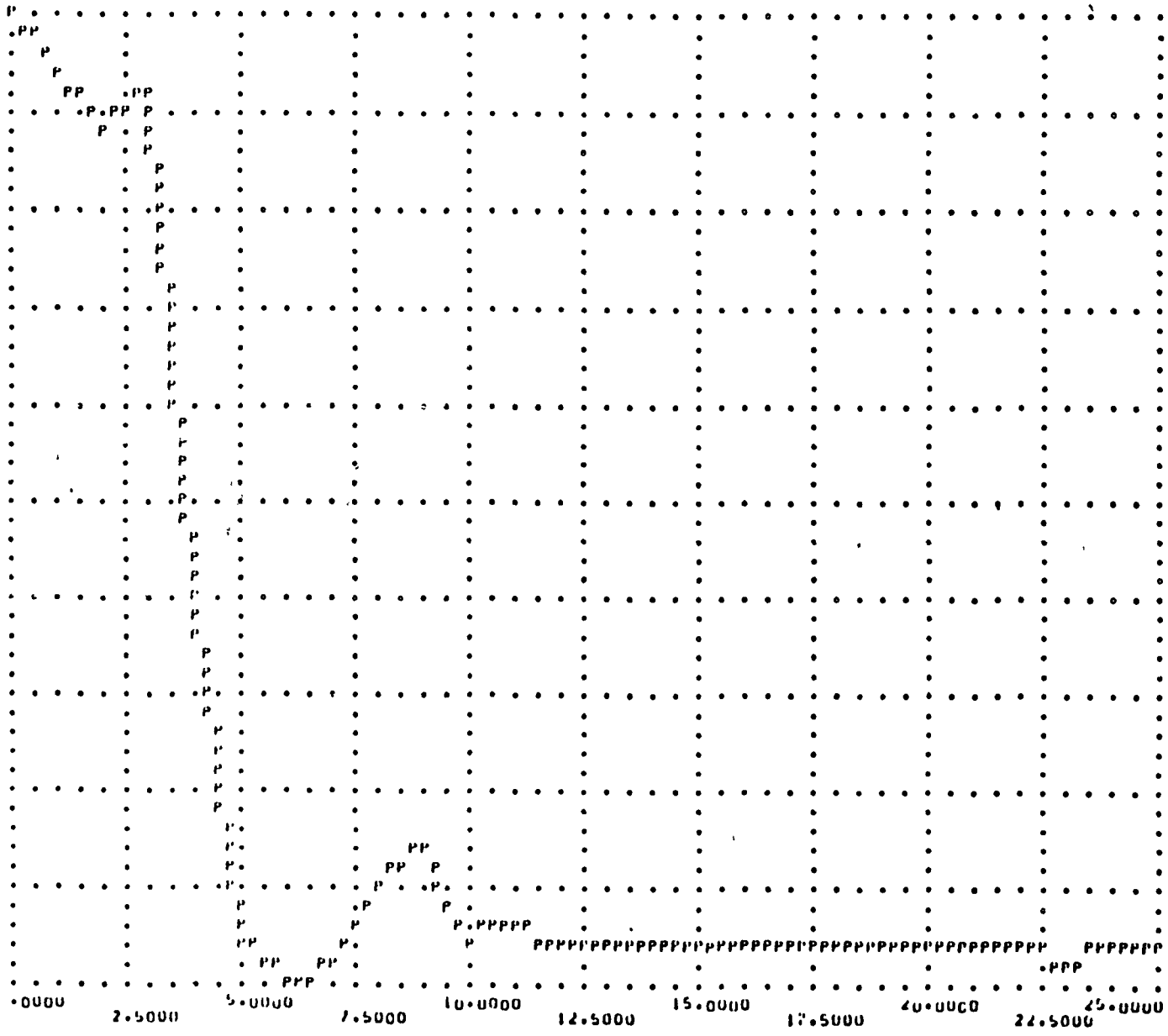
```
ALPHA =  3.0536-02

AFTER RUPDAT RDOT   =  3.1453+00  RDOTRS = 6.9986+00

BETA =  4.4990-01

C =  4.5771+00  CS =  7.9590+00  R-TILDA DOT R-TILDA =  8.7925-01  UDOTU =  5.5707+01
  ITER =   2940C=-6.5903-13  SWPC=-1.7939+03  AUNC= 9.7517-01  PC=-1.0959+01  RC=-2.2000-02  UC =-3.6229-02
PCOND =   -1.0959+01   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
QCOND =   -6.5903-13   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
AFTER LOOP COPROD UDOTAU =  1.0574+01

ALPHA =  1.6934-01

AFTER RUPDAT RDOTR =  1.0991+02  RDOTRS = 3.1453+00

BETA =  3.4995+01

C =  1.6095+02  CS =  4.5771+00  R-TILDA DOT R-TILDA =  6.8715-01  UDOTU =  1.4396+01
  ITER =   2940C=-6.5903-13  SWPC=-1.7939+03  AUNC=-5.8035+01  PC=-1.0965+01  RC= 9.8057+00  UC = 8.5397+00
PCOND =   -1.0965+01   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
QCOND =   -6.5903-13   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
AFTER LOOP COPROD UDOTAU =  1.6480+05

ALPHA =  6.6697-04

AFTER RUPDAT RDOTR =  1.3010+01  RDOTRS = 1.0991+02

BETA =  1.1837-01

C =  2.0051+01  CS =  1.6095+02  R-TILDA DOT R-TILDA =  6.8288-01  UDOTU =  1.7690+04
  ITER =   2940C=-6.5903-13  SWPC=-1.7939+03  AUNC= 1.6278+04  PC=-1.0959+01  RC=-1.0512+00  UC =-4.0425-02
PCOND =   -1.0959+01   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
QCOND =   -6.5903-13   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
AFTER LOOP COPROD UDOTAU =  6.8647+02

ALPHA =  1.8952-02

AFTER RUPDAT RDOTR =  1.9046+00  RDOTRS = 1.3010+01

BETA =  1.4635-01

C =  3.9345+00  CS =  2.0051+01  R-TILDA DOT R-TILDA =  6.4883-01  UDOTU =  2.6085+02
PCOND =   -1.0960+01   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
QCOND =   -1.3985-02   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
```

ALOG10(RDOTR) VS. ITERATION NUMBER




ALOG10(UDOTAU) VS. ITERATION NUMBER
6.1313
5.4994
4.8675
4.2355
3.6036
2.9717
2.3398
1.7079
1.0760
.4440
-.1879
.0000
2.5000
5.0000
7.5000
10.0000
12.5000
15.0000
17.5000
20.0000
22.5000
25.0000

PICOND. II VS. ITERATION NUMBER



```
          CYCLE     2          TIME =     1.000-03 SECONDS.

QSUM = -2.1627+02
PCOND = -1.0960+01   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
QCOND = -1.3985-02   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
-----------------------------------------------------------------------------

  SURFACE CELL NO.     4                                   CODE =        011011106302
                                                           LOCATION =     8  9  8
                                                           NORMAL =      -1  0 -1
                                                           MATERIAL =   TEFLON
                              POTENTIAL =  -1.096+01 VOLTS
                              FIELD =    4.757-01 VOLTS/METER
   FLUXES IN A/M**2
         INCIDENT ELECTRONS                          3.16-06
              RESULTING BACKSCATTER                  8.60-07
              RESULTING SECONDARIES                  1.32-06
         INCIDENT PROTONS                            7.39-08
              RESULTING SECONDARIES                  7.17-07
         PHOTOCURRENT                                0.00
                                                   -----------
       NET FLUX                                     -1.96-07
-----------------------------------------------------------------------------

  SURFACE CELL NO.    15                                   CODE =        011112100702
                                                           LOCATION =     9 10  8
                                                           NORMAL =       0  1 -1
                                                           MATERIAL =   TEFLON
                              POTENTIAL =  -1.096+01 VOLTS
                              FIELD =    7.665-03 VOLTS/METER
   FLUXES IN A/M**2
         INCIDENT ELECTRONS                          3.16-06
              RESULTING BACKSCATTER                  8.60-07
              RESULTING SECONDARIES                  1.32-06
         INCIDENT PROTONS                            7.39-08
              RESULTING SECONDARIES                  7.17-07
         PHOTOCURRENT                                0.00
                                                   -----------
       NET FLUX                                     -1.96-07

          NET CHARGING CURRENT =  -1.98+05 (CODE UNITS/SEC.).

     CHARGE PART OF CYCLE     2 COMPLETE.
    TIME HAS BEEN UPDATED TO      2.400-03 SECONDS.

CNOW ARRAY

  -1.4797+01   -2.3740+01   -1.4345+01   -2.3740+01   -1.6785+01   -2.3299+01   -1.4345+01   -2.3299+01   -1.4183+01   -2.3740+01
  -1.6785+01   -2.3299+01   -1.6785+01   -1.6340+01   -2.3299+01   -1.6340+01   -2.3049+01   -1.4345+01   -2.3299+01   -1.4183+01
  -2.3299+01   -1.6340+01   -2.3049+01   -1.4183+01   -2.3049+01   -1.4078+01
```

```
QSUM = -4.9403E-02
PCOND = -2.5036E-01   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
QCOND = -1.3985E-02   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

UNIT NO.  10    2 GRIDS

P(I,J, 1, 1)

-2.8E+00-3.0E+00-3.1E+00-3.2E+00-3.3E+00-3.4E+00-3.4E+00-3.5E+00-3.5E+00-3.5E+00-3.4E+00-3.4E+00-3.3E+00-3.2E+00-3.1E+00-3.0E+00-2.8E+00
-3.0E+00-3.1E+00-3.2E+00-3.4E+00-3.5E+00-3.6E+00-3.6E+00-3.7E+00-3.7E+00-3.7E+00-3.6E+00-3.6E+00-3.5E+00-3.4E+00-3.2E+00-3.1E+00-3.0E+00
-3.1E+00-3.2E+00-3.4E+00-3.5E+00-3.7E+00-3.8E+00-3.9E+00-3.9E+00-3.9E+00-3.9E+00-3.9E+00-3.8E+00-3.7E+00-3.5E+00-3.4E+00-3.2E+00-3.1E+00
-3.2E+00-3.4E+00-3.5E+00-3.7E+00-3.8E+00-4.0E+00-4.1E+00-4.1E+00-4.2E+00-4.1E+00-4.1E+00-4.0E+00-3.8E+00-3.7E+00-3.5E+00-3.4E+00-3.2E+00
-3.3E+00-3.5E+00-3.7E+00-3.8E+00-4.0E+00-4.2E+00-4.3E+00-4.4E+00-4.4E+00-4.4E+00-4.3E+00-4.2E+00-4.0E+00-3.8E+00-3.7E+00-3.5E+00-3.3E+00
-3.4E+00-3.6E+00-3.8E+00-4.0E+00-4.2E+00-4.3E+00-4.5E+00-4.5E+00-4.6E+00-4.5E+00-4.5E+00-4.3E+00-4.2E+00-4.0E+00-3.8E+00-3.6E+00-3.4E+00
-3.4E+00-3.6E+00-3.9E+00-4.1E+00-4.3E+00-4.5E+00-4.6E+00-4.7E+00-4.7E+00-4.7E+00-4.6E+00-4.5E+00-4.3E+00-4.1E+00-3.9E+00-3.6E+00-3.4E+00
-3.5E+00-3.7E+00-3.9E+00-4.1E+00-4.4E+00-4.5E+00-4.7E+00-4.8E+00-4.8E+00-4.8E+00-4.7E+00-4.5E+00-4.4E+00-4.2E+00-3.9E+00-3.7E+00-3.5E+00
-3.5E+00-3.7E+00-3.9E+00-4.2E+00-4.4E+00-4.6E+00-4.7E+00-4.8E+00-4.8E+00-4.8E+00-4.7E+00-4.6E+00-4.4E+00-4.2E+00-3.9E+00-3.7E+00-3.5E+00
-3.5E+00-3.7E+00-3.9E+00-4.1E+00-4.4E+00-4.5E+00-4.7E+00-4.8E+00-4.8E+00-4.8E+00-4.7E+00-4.6E+00-4.4E+00-4.2E+00-3.9E+00-3.7E+00-3.5E+00
-3.4E+00-3.6E+00-3.9E+00-4.1E+00-4.3E+00-4.5E+00-4.6E+00-4.7E+00-4.7E+00-4.7E+00-4.6E+00-4.5E+00-4.3E+00-4.1E+00-3.9E+00-3.6E+00-3.4E+00
-3.4E+00-3.6E+00-3.8E+00-4.0E+00-4.2E+00-4.3E+00-4.5E+00-4.5E+00-4.6E+00-4.6E+00-4.5E+00-4.3E+00-4.2E+00-4.0E+00-3.8E+00-3.6E+00-3.4E+00
-3.3E+00-3.5E+00-3.7E+00-3.8E+00-4.0E+00-4.2E+00-4.3E+00-4.4E+00-4.4E+00-4.4E+00-4.3E+00-4.2E+00-4.0E+00-3.8E+00-3.7E+00-3.5E+00-3.3E+00
-3.2E+00-3.4E+00-3.5E+00-3.7E+00-3.8E+00-4.0E+00-4.1E+00-4.2E+00-4.2E+00-4.2E+00-4.1E+00-4.0E+00-3.8E+00-3.7E+00-3.5E+00-3.4E+00-3.2E+00
-3.1E+00-3.2E+00-3.4E+00-3.5E+00-3.7E+00-3.8E+00-3.9E+00-3.9E+00-3.9E+00-3.9E+00-3.9E+00-3.8E+00-3.7E+00-3.5E+00-3.4E+00-3.2E+00-3.1E+00
-3.0E+00-3.1E+00-3.2E+00-3.4E+00-3.5E+00-3.6E+00-3.6E+00-3.7E+00-3.7E+00-3.7E+00-3.6E+00-3.6E+00-3.5E+00-3.4E+00-3.2E+00-3.1E+00-3.0E+00
-2.8E+00-3.0E+00-3.1E+00-3.2E+00-3.3E+00-3.4E+00-3.4E+00-3.5E+00-3.5E+00-3.5E+00-3.4E+00-3.4E+00-3.3E+00-3.2E+00-3.1E+00-3.0E+00-2.8E+00

P(I,J, 2, 1)

-3.0E+00-3.1E+00-3.2E+00-3.4E+00-3.5E+00-3.6E+00-3.6E+00-3.7E+00-3.7E+00-3.7E+00-3.6E+00-3.6E+00-3.5E+00-3.4E+00-3.2E+00-3.1E+00-3.0E+00
-3.1E+00-3.3E+00-3.4E+00-3.6E+00-3.7E+00-3.8E+00-3.9E+00-4.0E+00-4.0E+00-4.0E+00-3.9E+00-3.8E+00-3.7E+00-3.6E+00-3.4E+00-3.3E+00-3.1E+00
-3.2E+00-3.4E+00-3.6E+00-3.8E+00-3.9E+00-4.1E+00-4.2E+00-4.2E+00-4.3E+00-4.2E+00-4.2E+00-4.1E+00-3.9E+00-3.8E+00-3.6E+00-3.4E+00-3.2E+00
-3.4E+00-3.6E+00-3.8E+00-4.0E+00-4.1E+00-4.3E+00-4.4E+00-4.5E+00-4.5E+00-4.5E+00-4.4E+00-4.3E+00-4.1E+00-4.0E+00-3.8E+00-3.6E+00-3.4E+00
-3.5E+00-3.7E+00-3.7E+00-4.1E+00-4.4E+00-4.5E+00-4.7E+00-4.8E+00-4.8E+00-4.8E+00-4.7E+00-4.5E+00-4.4E+00-4.1E+00-3.9E+00-3.7E+00-3.5E+00
-3.6E+00-3.8E+00-4.1E+00-4.3E+00-4.5E+00-4.7E+00-4.9E+00-5.0E+00-5.0E+00-5.0E+00-4.9E+00-4.8E+00-4.5E+00-4.3E+00-4.1E+00-3.8E+00-3.6E+00
-3.6E+00-3.9E+00-4.2E+00-4.4E+00-4.7E+00-4.9E+00-5.0E+00-5.2E+00-5.2E+00-5.2E+00-5.1E+00-4.9E+00-4.7E+00-4.4E+00-4.2E+00-3.9E+00-3.6E+00
-3.7E+00-4.0E+00-4.2E+00-4.5E+00-4.8E+00-5.0E+00-5.2E+00-5.3E+00-5.3E+00-5.3E+00-5.2E+00-5.0E+00-4.8E+00-4.5E+00-4.2E+00-4.0E+00-3.7E+00
-3.7E+00-4.0E+00-4.3E+00-4.5E+00-4.8E+00-5.0E+00-5.2E+00-5.3E+00-5.4E+00-5.4E+00-5.3E+00-5.1E+00-4.8E+00-4.6E+00-4.3E+00-4.0E+00-3.7E+00
-3.7E+00-4.0E+00-4.2E+00-4.5E+00-4.8E+00-5.0E+00-5.2E+00-5.3E+00-5.4E+00-5.3E+00-5.2E+00-5.1E+00-4.8E+00-4.5E+00-4.2E+00-4.0E+00-3.7E+00
-3.6E+00-3.9E+00-4.2E+00-4.4E+00-4.7E+00-4.9E+00-5.1E+00-5.2E+00-5.3E+00-5.2E+00-5.1E+00-5.0E+00-4.7E+00-4.5E+00-4.2E+00-3.9E+00-3.6E+00
-3.6E+00-3.8E+00-4.1E+00-4.3E+00-4.5E+00-4.8E+00-4.9E+00-5.0E+00-5.1E+00-5.1E+00-5.0E+00-4.8E+00-4.6E+00-4.3E+00-4.1E+00-3.8E+00-3.6E+00
-3.5E+00-3.7E+00-3.9E+00-4.1E+00-4.4E+00-4.5E+00-4.7E+00-4.8E+00-4.8E+00-4.8E+00-4.7E+00-4.6E+00-4.4E+00-4.2E+00-3.9E+00-3.7E+00-3.5E+00
-3.4E+00-3.6E+00-3.8E+00-4.0E+00-4.1E+00-4.3E+00-4.4E+00-4.5E+00-4.6E+00-4.5E+00-4.5E+00-4.3E+00-4.2E+00-4.0E+00-3.8E+00-3.6E+00-3.4E+00
-3.2E+00-3.4E+00-3.6E+00-3.8E+00-3.9E+00-4.1E+00-4.2E+00-4.2E+00-4.3E+00-4.2E+00-4.2E+00-4.1E+00-3.9E+00-3.8E+00-3.6E+00-3.4E+00-3.2E+00
-3.1E+00-3.3E+00-3.4E+00-3.6E+00-3.7E+00-3.8E+00-3.9E+00-4.0E+00-4.0E+00-4.0E+00-3.9E+00-3.8E+00-3.7E+00-3.6E+00-3.4E+00-3.3E+00-3.1E+00
-3.0E+00-3.1E+00-3.2E+00-3.4E+00-3.5E+00-3.6E+00-3.6E+00-3.7E+00-3.7E+00-3.7E+00-3.6E+00-3.6E+00-3.5E+00-3.4E+00-3.2E+00-3.1E+00-3.0E+00

P(I,J, 3, 1)
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```
-3.1+00-3.2+00-3.4+00-3.5+00-3.7+00-3.8+00-3.9+00-3.9+00-3.9+00-3.9+00-3.9+00-3.8+00-3.7+00-3.5+00-3.4+00-3.2+00-3.1+00
-3.2+00-3.4+00-3.6+00-3.8+00-3.9+00-4.1+00-4.2+00-4.2+00-4.3+00-4.2+00-4.2+00-4.1+00-3.9+00-3.8+00-3.6+00-3.4+00-3.2+00
-3.4+00-3.6+00-3.8+00-4.0+00-4.2+00-4.4+00-4.5+00-4.6+00-4.6+00-4.6+00-4.5+00-4.4+00-4.2+00-4.0+00-3.8+00-3.6+00-3.4+00
-3.5+00-3.6+00-4.0+00-4.2+00-4.5+00-4.6+00-4.8+00-4.9+00-4.9+00-4.9+00-4.8+00-4.7+00-4.5+00-4.2+00-4.0+00-3.6+00-3.5+00
-3.7+00-3.9+00-4.2+00-4.5+00-4.7+00-4.9+00-5.1+00-5.2+00-5.2+00-5.2+00-5.1+00-5.0+00-4.7+00-4.5+00-4.2+00-3.9+00-3.7+00
-3.8+00-4.1+00-4.4+00-4.6+00-4.9+00-5.1+00-5.3+00-5.5+00-5.5+00-5.5+00-5.4+00-5.2+00-5.0+00-4.7+00-4.4+00-4.1+00-3.8+00
-3.9+00-4.2+00-4.5+00-4.8+00-5.1+00-5.3+00-5.5+00-5.7+00-5.8+00-5.8+00-5.7+00-5.5+00-5.2+00-4.9+00-4.5+00-4.2+00-3.9+00
-3.9+00-4.2+00-4.6+00-4.9+00-5.2+00-5.5+00-5.7+00-5.9+00-6.0+00-6.0+00-5.9+00-5.6+00-5.3+00-5.0+00-4.6+00-4.2+00-3.9+00
-3.9+00-4.3+00-4.6+00-4.9+00-5.2+00-5.5+00-5.8+00-6.0+00-6.1+00-6.1+00-6.0+00-5.7+00-5.4+00-5.0+00-4.6+00-4.3+00-3.9+00
-3.9+00-4.2+00-4.6+00-4.9+00-5.2+00-5.5+00-5.8+00-6.0+00-6.1+00-6.1+00-6.0+00-5.7+00-5.4+00-5.0+00-4.6+00-4.3+00-3.9+00
-3.9+00-4.2+00-4.5+00-4.8+00-5.1+00-5.4+00-5.7+00-5.9+00-6.0+00-6.0+00-5.8+00-5.6+00-5.3+00-4.9+00-4.5+00-4.2+00-3.9+00
-3.8+00-4.1+00-4.4+00-4.7+00-5.0+00-5.2+00-5.5+00-5.7+00-5.7+00-5.7+00-5.6+00-5.3+00-5.1+00-4.7+00-4.4+00-4.1+00-3.8+00
-3.7+00-3.9+00-4.2+00-4.5+00-4.7+00-5.0+00-5.2+00-5.3+00-5.4+00-5.4+00-5.3+00-5.1+00-4.8+00-4.5+00-4.2+00-3.9+00-3.7+00
-3.5+00-3.8+00-4.0+00-4.2+00-4.5+00-4.7+00-4.9+00-5.0+00-5.0+00-5.0+00-4.9+00-4.7+00-4.5+00-4.3+00-4.0+00-3.8+00-3.5+00
-3.4+00-3.6+00-3.8+00-4.0+00-4.2+00-4.4+00-4.5+00-4.6+00-4.6+00-4.6+00-4.5+00-4.4+00-4.2+00-4.0+00-3.8+00-3.6+00-3.4+00
-3.2+00-3.4+00-3.6+00-3.8+00-3.9+00-4.1+00-4.2+00-4.2+00-4.3+00-4.2+00-4.1+00-3.9+00-3.8+00-3.6+00-3.4+00-3.2+00
-3.1+00-3.2+00-3.4+00-3.5+00-3.7+00-3.8+00-3.9+00-3.9+00-3.9+00-3.9+00-3.8+00-3.7+00-3.5+00-3.4+00-3.2+00-3.1+00
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P(I,J, 4, 1)

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-3.2+00-3.4+00-3.5+00-3.7+00-3.8+00-4.0+00-4.1+00-4.1+00-4.2+00-4.1+00-4.1+00-4.0+00-3.8+00-3.7+00-3.5+00-3.4+00-3.2+00
-3.4+00-3.6+00-3.8+00-4.0+00-4.1+00-4.3+00-4.4+00-4.5+00-4.5+00-4.5+00-4.4+00-4.3+00-4.1+00-4.0+00-3.8+00-3.6+00-3.4+00
-3.5+00-3.8+00-4.0+00-4.2+00-4.4+00-4.6+00-4.8+00-4.9+00-4.9+00-4.9+00-4.8+00-4.7+00-4.5+00-4.2+00-4.0+00-3.6+00-3.5+00
-3.7+00-4.0+00-4.2+00-4.5+00-4.8+00-5.0+00-5.1+00-5.3+00-5.3+00-5.3+00-5.2+00-5.0+00-4.8+00-4.5+00-4.2+00-4.0+00-3.7+00
-3.8+00-4.1+00-4.4+00-4.8+00-5.0+00-5.3+00-5.5+00-5.7+00-5.7+00-5.7+00-5.6+00-5.4+00-5.1+00-4.8+00-4.5+00-4.1+00-3.8+00
-4.0+00-4.3+00-4.6+00-5.0+00-5.3+00-5.6+00-5.9+00-6.1+00-6.2+00-6.2+00-6.0+00-5.8+00-5.4+00-5.1+00-4.7+00-4.3+00-4.0+00
-4.1+00-4.4+00-4.8+00-5.1+00-5.5+00-5.9+00-6.2+00-6.5+00-6.6+00-6.6+00-6.4+00-6.1+00-5.7+00-5.3+00-4.9+00-4.5+00-4.1+00
-4.1+00-4.5+00-4.9+00-5.3+00-5.7+00-6.1+00-6.5+00-6.8+00-7.0+00-7.0+00-6.8+00-6.4+00-6.0+00-5.5+00-5.0+00-4.6+00-4.2+00
-4.2+00-4.5+00-4.9+00-5.3+00-5.7+00-6.2+00-6.6+00-7.0+00-7.2+00-7.2+00-6.9+00-6.5+00-6.1+00-5.6+00-5.1+00-4.6+00-4.2+00
-4.1+00-4.5+00-4.9+00-5.3+00-5.7+00-6.2+00-6.6+00-7.0+00-7.2+00-7.2+00-6.9+00-6.5+00-6.0+00-5.5+00-5.0+00-4.6+00-4.2+00
-4.1+00-4.4+00-4.8+00-5.2+00-5.6+00-6.0+00-6.4+00-6.8+00-6.9+00-6.9+00-6.7+00-6.3+00-5.9+00-5.4+00-4.9+00-4.5+00-4.1+00
-4.0+00-4.3+00-4.7+00-5.0+00-5.4+00-5.8+00-6.1+00-6.4+00-6.5+00-6.5+00-6.3+00-6.0+00-5.6+00-5.2+00-4.8+00-4.3+00-4.0+00
-3.8+00-4.1+00-4.5+00-4.8+00-5.1+00-5.4+00-5.7+00-6.0+00-6.1+00-6.0+00-5.9+00-5.6+00-5.3+00-4.9+00-4.5+00-4.2+00-3.8+00
-3.7+00-4.0+00-4.2+00-4.5+00-4.8+00-5.1+00-5.3+00-5.5+00-5.6+00-5.5+00-5.4+00-5.2+00-4.9+00-4.6+00-4.3+00-4.0+00-3.7+00
-3.5+00-3.8+00-4.0+00-4.2+00-4.5+00-4.7+00-4.9+00-5.0+00-5.1+00-5.0+00-4.9+00-4.8+00-4.5+00-4.3+00-4.0+00-3.8+00-3.5+00
-3.4+00-3.6+00-3.8+00-4.0+00-4.1+00-4.3+00-4.5+00-4.6+00-4.6+00-4.6+00-4.5+00-4.3+00-4.2+00-4.0+00-3.8+00-3.6+00-3.4+00
-3.2+00-3.4+00-3.5+00-3.7+00-3.8+00-4.0+00-4.1+00-4.2+00-4.2+00-4.2+00-4.1+00-4.0+00-3.8+00-3.7+00-3.5+00-3.4+00-3.2+00
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P(I,J, 5, 1)

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-3.3+00-3.5+00-3.7+00-3.8+00-4.0+00-4.2+00-4.3+00-4.3+00-4.4+00-4.3+00-4.3+00-4.2+00-4.0+00-3.8+00-3.7+00-3.5+00-3.3+00
-3.5+00-3.7+00-3.9+00-4.1+00-4.3+00-4.5+00-4.7+00-4.8+00-4.8+00-4.8+00-4.7+00-4.5+00-4.4+00-4.1+00-3.9+00-3.7+00-3.5+00
-3.7+00-3.9+00-4.2+00-4.4+00-4.7+00-4.9+00-5.1+00-5.2+00-5.2+00-5.2+00-5.1+00-4.9+00-4.7+00-4.5+00-4.2+00-3.9+00-3.7+00
-3.8+00-4.1+00-4.4+00-4.8+00-5.0+00-5.3+00-5.5+00-5.7+00-5.7+00-5.7+00-5.6+00-5.4+00-5.1+00-4.8+00-4.5+00-4.1+00-3.8+00
-4.0+00-4.3+00-4.7+00-5.0+00-5.4+00-5.7+00-6.0+00-6.2+00-6.3+00-6.3+00-6.2+00-5.9+00-5.5+00-5.2+00-4.8+00-4.4+00-4.0+00
-4.2+00-4.5+00-4.9+00-5.3+00-5.7+00-6.1+00-6.5+00-6.9+00-7.0+00-7.0+00-6.8+00-6.4+00-6.0+00-5.5+00-5.0+00-4.6+00-4.2+00
-4.3+00-4.7+00-5.1+00-5.5+00-6.0+00-6.5+00-7.1+00-7.5+00-7.7+00-7.7+00-7.4+00-7.0+00-6.4+00-5.8+00-5.1+00-4.7+00-4.3+00
-4.3+00-4.8+00-5.2+00-5.7+00-6.2+00-6.9+00-7.5+00-8.1+00-8.3+00-8.3+00-8.0+00-7.4+00-6.7+00-6.1+00-5.4+00-4.9+00-4.4+00
-4.4+00-4.8+00-5.2+00-5.7+00-6.3+00-7.0+00-7.7+00-8.3+00-8.7+00-8.6+00-8.3+00-7.6+00-6.9+00-6.2+00-5.5+00-4.9+00-4.4+00
-4.3+00-4.8+00-5.2+00-5.7+00-6.3+00-7.0+00-7.7+00-8.3+00-8.6+00-8.6+00-8.2+00-7.4+00-6.9+00-6.2+00-5.5+00-4.9+00-4.4+00
-4.3+00-4.7+00-5.1+00-5.6+00-6.2+00-6.8+00-7.4+00-8.0+00-8.3+00-8.2+00-7.9+00-7.2+00-6.7+00-6.0+00-5.4+00-4.8+00-4.3+00
-4.2+00-4.5+00-4.9+00-5.4+00-5.9+00-6.4+00-7.0+00-7.4+00-7.6+00-7.6+00-7.3+00-6.9+00-6.3+00-5.7+00-5.1+00-4.6+00-4.2+00
-4.0+00-4.4+00-4.7+00-5.1+00-5.5+00-6.0+00-6.4+00-6.7+00-6.9+00-6.9+00-6.7+00-6.3+00-5.8+00-5.3+00-4.9+00-4.4+00-4.0+00
-3.8+00-4.1+00-4.5+00-4.8+00-5.2+00-5.5+00-5.8+00-6.1+00-6.2+00-6.2+00-6.0+00-5.7+00-5.3+00-4.9+00-4.5+00-4.2+00-3.9+00
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-3.7+00-3.9+00-4.2+00-4.5+00-4.8+00-5.0+00-5.3+00-5.4+00-5.5+00-5.5+00-5.4+00-5.1+00-4.9+00-4.5+00-4.2+00-3.9+00-3.7+00
-3.5+00-3.7+00-3.9+00-4.1+00-4.4+00-4.6+00-4.7+00-4.9+00-4.9+00-4.9+00-4.8+00-4.6+00-4.4+00-4.2+00-3.9+00-3.7+00-3.5+00
-3.3+00-3.5+00-3.7+00-3.8+00-4.0+00-4.2+00-4.3+00-4.4+00-4.4+00-4.4+00-4.3+00-4.2+00-4.0+00-3.9+00-3.7+00-3.5+00-3.3+00

P(I,J, 6, 1)

-3.4+00-3.6+00-3.8+00-4.0+00-4.2+00-4.3+00-4.4+00-4.5+00-4.5+00-4.5+00-4.4+00-4.3+00-4.2+00-4.0+00-3.8+00-3.6+00-3.4+00
-3.6+00-3.8+00-4.0+00-4.3+00-4.5+00-4.7+00-4.9+00-5.0+00-5.0+00-5.0+00-4.9+00-4.7+00-4.5+00-4.3+00-4.1+00-3.8+00-3.6+00
-3.8+00-4.0+00-4.3+00-4.6+00-4.9+00-5.1+00-5.3+00-5.5+00-5.5+00-5.5+00-5.4+00-5.2+00-5.0+00-4.7+00-4.4+00-4.1+00-3.8+00
-4.0+00-4.3+00-4.6+00-5.0+00-5.3+00-5.6+00-5.9+00-6.1+00-6.2+00-6.2+00-6.0+00-5.8+00-5.4+00-5.1+00-4.7+00-4.3+00-4.0+00
-4.2+00-4.5+00-4.9+00-5.3+00-5.7+00-6.1+00-6.5+00-6.9+00-7.0+00-7.0+00-6.8+00-6.4+00-6.0+00-5.5+00-5.0+00-4.6+00-4.2+00
-4.3+00-4.7+00-5.1+00-5.6+00-6.1+00-6.7+00-7.3+00-7.8+00-8.1+00-8.1+00-7.8+00-7.2+00-6.6+00-5.9+00-5.4+00-4.8+00-4.4+00
-4.4+00-4.7+00-5.3+00-5.9+00-6.5+00-7.3+00-8.1+00-8.8+00-9.2+00-9.2+00-8.7+00-8.0+00-7.2+00-6.4+00-5.6+00-5.0+00-4.5+00
-4.5+00-5.0+00-5.5+00-6.1+00-6.9+00-7.8+00-8.8+00-9.8+00-1.0+01-1.0+01-9.7+00-8.7+00-7.7+00-6.7+00-5.9+00-5.2+00-4.6+00
-4.5+00-5.0+00-5.5+00-6.2+00-7.0+00-8.1+00-9.2+00-1.0+01-1.1+01-1.1+01-1.0+01-9.1+00-7.9+00-6.9+00-6.0+00-5.2+00-4.6+00
-4.5+00-5.0+00-5.5+00-6.2+00-7.0+00-8.1+00-9.2+00-1.0+01-1.1+01-1.1+01-1.0+01-9.1+00-7.9+00-6.8+00-6.0+00-5.2+00-4.6+00
-4.4+00-4.9+00-5.4+00-6.0+00-6.8+00-7.8+00-8.7+00-9.7+00-1.0+01-1.0+01-9.6+00-8.6+00-7.6+00-6.6+00-5.8+00-5.1+00-4.5+00
-4.3+00-4.7+00-5.2+00-5.8+00-6.4+00-7.2+00-8.0+00-8.7+00-9.1+00-9.1+00-8.6+00-7.9+00-7.1+00-6.3+00-5.5+00-4.9+00-4.4+00
-4.2+00-4.5+00-5.0+00-5.4+00-6.0+00-6.6+00-7.2+00-7.7+00-7.9+00-7.9+00-7.6+00-7.1+00-6.4+00-5.8+00-5.2+00-4.6+00-4.2+00
-4.0+00-4.3+00-4.7+00-5.1+00-5.5+00-5.9+00-6.4+00-6.7+00-6.9+00-6.8+00-6.6+00-6.3+00-5.8+00-5.3+00-4.8+00-4.4+00-4.0+00
-3.8+00-4.1+00-4.4+00-4.7+00-5.0+00-5.4+00-5.6+00-5.9+00-6.0+00-6.0+00-5.8+00-5.5+00-5.2+00-4.8+00-4.4+00-4.1+00-3.8+00
-3.6+00-3.8+00-4.1+00-4.3+00-4.6+00-4.8+00-5.0+00-5.2+00-5.2+00-5.2+00-5.1+00-4.9+00-4.6+00-4.4+00-4.1+00-3.8+00-3.6+00
-3.4+00-3.6+00-3.8+00-4.0+00-4.2+00-4.4+00-4.5+00-4.6+00-4.6+00-4.6+00-4.5+00-4.4+00-4.2+00-4.0+00-3.8+00-3.6+00-3.4+00

P(I,J, 7, 1)

-3.4+00-3.6+00-3.9+00-4.1+00-4.3+00-4.4+00-4.6+00-4.7+00-4.7+00-4.7+00-4.6+00-4.4+00-4.3+00-4.1+00-3.9+00-3.6+00-3.4+00
-3.6+00-3.9+00-4.2+00-4.4+00-4.7+00-4.9+00-5.0+00-5.1+00-5.2+00-5.2+00-5.1+00-4.9+00-4.7+00-4.4+00-4.2+00-3.9+00-3.6+00
-3.9+00-4.2+00-4.5+00-4.8+00-5.1+00-5.3+00-5.5+00-5.7+00-5.8+00-5.8+00-5.7+00-5.4+00-5.2+00-4.8+00-4.5+00-4.2+00-3.9+00
-4.1+00-4.4+00-4.8+00-5.1+00-5.5+00-5.9+00-6.2+00-6.5+00-6.6+00-6.6+00-6.4+00-6.1+00-5.7+00-5.3+00-4.9+00-4.5+00-4.1+00
-4.3+00-4.7+00-5.1+00-5.5+00-6.0+00-6.5+00-7.1+00-7.5+00-7.7+00-7.7+00-7.4+00-7.0+00-6.4+00-5.8+00-5.3+00-4.7+00-4.3+00
-4.4+00-4.9+00-5.3+00-5.9+00-6.5+00-7.3+00-8.1+00-8.8+00-9.2+00-9.2+00-8.7+00-8.0+00-7.2+00-6.4+00-5.6+00-5.0+00-4.5+00
-4.6+00-5.0+00-5.5+00-6.2+00-7.1+00-8.1+00-9.2+00-1.0+01-1.1+01-1.1+01-1.0+01-9.2+00-8.0+00-6.9+00-6.0+00-5.3+00-4.7+00
-4.7+00-5.1+00-5.7+00-6.5+00-7.5+00-8.8+00-1.0+01-1.2+01-1.3+01-1.3+01-1.2+01-1.0+01-8.7+00-7.3+00-6.3+00-5.4+00-4.6+00
-4.7+00-5.2+00-5.8+00-6.6+00-7.7+00-9.2+00-1.1+01-1.3+01-1.5+01-1.5+01-1.3+01-1.1+01-9.1+00-7.5+00-6.4+00-5.5+00-4.6+00
-4.7+00-5.2+00-5.8+00-6.6+00-7.7+00-9.2+00-1.1+01-1.3+01-1.5+01-1.5+01-1.3+01-1.1+01-9.1+00-7.5+00-6.4+00-5.5+00-4.6+00
-4.6+00-5.1+00-5.7+00-6.4+00-7.4+00-8.7+00-1.0+01-1.2+01-1.3+01-1.3+01-1.2+01-1.0+01-8.6+00-7.3+00-6.2+00-5.4+00-4.7+00
-4.4+00-4.9+00-5.4+00-6.1+00-7.0+00-8.0+00-9.2+00-1.0+01-1.1+01-1.1+01-1.0+01-9.1+00-7.9+00-6.8+00-5.9+00-5.2+00-4.6+00
-4.3+00-4.7+00-5.2+00-5.7+00-6.4+00-7.2+00-8.0+00-8.7+00-9.1+00-9.1+00-8.6+00-7.9+00-7.0+00-6.2+00-5.5+00-4.9+00-4.3+00
-4.1+00-4.4+00-4.8+00-5.3+00-5.8+00-6.4+00-6.9+00-7.3+00-7.5+00-7.5+00-7.3+00-6.8+00-6.2+00-5.6+00-5.0+00-4.5+00-4.1+00
-3.9+00-4.2+00-4.5+00-4.9+00-5.3+00-5.6+00-6.0+00-6.3+00-6.4+00-6.4+00-6.2+00-5.9+00-5.5+00-5.0+00-4.6+00-4.2+00-3.9+00
-3.6+00-3.9+00-4.2+00-4.5+00-4.7+00-5.0+00-5.3+00-5.4+00-5.5+00-5.5+00-5.4+00-5.2+00-4.9+00-4.5+00-4.2+00-3.9+00-3.6+00
-3.4+00-3.6+00-3.9+00-4.1+00-4.3+00-4.5+00-4.7+00-4.8+00-4.8+00-4.8+00-4.7+00-4.6+00-4.3+00-4.1+00-3.9+00-3.6+00-3.4+00

P(I,J, 8, 1)

-3.5+00-3.7+00-3.9+00-4.1+00-4.3+00-4.5+00-4.7+00-4.7+00-4.8+00-4.8+00-4.7+00-4.5+00-4.3+00-4.1+00-3.9+00-3.7+00-3.5+00
-3.7+00-3.9+00-4.2+00-4.5+00-4.7+00-5.0+00-5.1+00-5.3+00-5.3+00-5.3+00-5.2+00-5.0+00-4.8+00-4.5+00-4.2+00-4.0+00-3.7+00
-3.9+00-4.2+00-4.6+00-4.9+00-5.2+00-5.5+00-5.7+00-5.9+00-6.0+00-6.0+00-5.9+00-5.6+00-5.3+00-5.0+00-4.6+00-4.2+00-3.9+00
-4.1+00-4.5+00-4.9+00-5.3+00-5.7+00-6.1+00-6.5+00-6.8+00-7.0+00-7.0+00-6.8+00-6.4+00-5.9+00-5.5+00-5.0+00-4.5+00-4.2+00
-4.3+00-4.7+00-5.2+00-5.7+00-6.2+00-6.9+00-7.5+00-8.1+00-8.3+00-8.3+00-8.0+00-7.4+00-6.7+00-6.0+00-5.4+00-4.9+00-4.4+00
-4.5+00-5.0+00-5.5+00-6.1+00-6.9+00-7.8+00-8.8+00-9.8+00-1.0+01-1.0+01-9.7+00-8.7+00-7.7+00-6.7+00-5.9+00-5.2+00-4.6+00
-4.7+00-5.1+00-5.7+00-6.5+00-7.5+00-8.8+00-1.0+01-1.2+01-1.3+01-1.3+01-1.2+01-1.0+01-8.7+00-7.3+00-6.3+00-5.4+00-4.6+00
-4.7+00-5.3+00-5.9+00-6.8+00-8.1+00-9.8+00-1.2+01-1.5+01-1.6+01-1.6+01-1.2+01-9.6+00-7.8+00-6.6+00-5.7+00-4.9+00
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-4.8+00-5.3+00-6.0+00-7.0+00-8.3+00-1.0+01-1.3+01-1.8+01-2.5+01-2.5+01-1.7+01-1.3+01-1.0+01-8.1+00-6.8+00-5.8+00-5.0+00
-4.8+00-5.3+00-6.0+00-7.0+00-8.3+00-1.0+01-1.3+01-1.8+01-2.5+01-2.5+01-1.7+01-1.3+01-1.0+01-8.1+00-6.7+00-5.7+00-5.0+00
-4.7+00-5.2+00-5.9+00-6.8+00-8.0+00-9.7+00-1.2+01-1.5+01-1.7+01-1.7+01-1.5+01-1.2+01-9.5+00-7.8+00-6.5+00-5.6+00-4.8+00
-4.5+00-5.0+00-5.6+00-6.4+00-7.4+00-8.7+00-1.0+01-1.2+01-1.3+01-1.3+01-1.2+01-1.0+01-8.6+00-7.2+00-6.2+00-5.3+00-4.7+00
-4.3+00-4.8+00-5.3+00-5.9+00-6.7+00-7.7+00-8.7+00-9.6+00-1.0+01-1.0+01-9.5+00-8.6+00-7.5+00-6.5+00-5.7+00-5.0+00-4.4+00
-4.1+00-4.5+00-5.0+00-5.5+00-6.0+00-6.7+00-7.3+00-7.8+00-8.1+00-8.1+00-7.8+00-7.2+00-6.5+00-5.9+00-5.2+00-4.7+00-4.2+00
-3.9+00-4.2+00-4.6+00-5.0+00-5.4+00-5.9+00-6.3+00-6.6+00-6.8+00-6.7+00-6.5+00-6.2+00-5.7+00-5.2+00-4.7+00-4.3+00-3.9+00
-3.7+00-4.0+00-4.2+00-4.5+00-4.9+00-5.2+00-5.4+00-5.7+00-5.8+00-5.7+00-5.6+00-5.3+00-5.0+00-4.7+00-4.3+00-4.0+00-3.7+00
-3.5+00-3.7+00-3.9+00-4.2+00-4.4+00-4.6+00-4.8+00-4.9+00-5.0+00-5.0+00-4.8+00-4.7+00-4.4+00-4.2+00-3.9+00-3.7+00-3.5+00
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P(I,J, 9, 1)

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-3.5+00-3.7+00-3.9+00-4.2+00-4.4+00-4.5+00-4.7+00-4.8+00-4.8+00-4.8+00-4.7+00-4.6+00-4.4+00-4.2+00-3.9+00-3.7+00-3.5+00
-3.7+00-4.0+00-4.2+00-4.5+00-4.8+00-5.0+00-5.2+00-5.3+00-5.4+00-5.3+00-5.2+00-5.1+00-4.8+00-4.6+00-4.3+00-4.0+00-3.7+00
-3.9+00-4.2+00-4.6+00-4.9+00-5.2+00-5.5+00-5.8+00-6.0+00-6.1+00-6.1+00-6.0+00-5.7+00-5.4+00-5.0+00-4.6+00-4.3+00-3.9+00
-4.2+00-4.5+00-4.9+00-5.3+00-5.7+00-6.2+00-6.6+00-7.0+00-7.2+00-7.2+00-6.9+00-6.5+00-6.1+00-5.6+00-5.1+00-4.6+00-4.2+00
-4.4+00-4.8+00-5.2+00-5.7+00-6.3+00-7.0+00-7.7+00-8.3+00-8.6+00-8.6+00-8.2+00-7.6+00-6.9+00-6.2+00-5.5+00-4.9+00-4.4+00
-4.5+00-5.0+00-5.5+00-6.2+00-7.0+00-8.1+00-9.2+00-1.0+01-1.1+01-1.1+01-1.0+01-9.1+00-7.9+00-6.9+00-6.0+00-5.2+00-4.6+00
-4.7+00-5.2+00-5.8+00-6.6+00-7.7+00-9.2+00-1.1+01-1.3+01-1.5+01-1.5+01-1.3+01-1.1+01-9.1+00-7.5+00-6.4+00-5.5+00-4.8+00
-4.8+00-5.3+00-6.0+00-7.0+00-8.3+00-1.0+01-1.3+01-1.8+01-2.5+01-2.5+01-1.7+01-1.3+01-1.0+01-8.1+00-6.8+00-5.8+00-5.0+00
-4.8+00-5.4+00-6.1+00-7.2+00-8.6+00-1.1+01-1.5+01-2.5+01 0.0    0.0   -2.5+01-1.5+01-1.1+01-8.5+00-6.9+00-5.9+00-5.0+00
-4.8+00-5.3+00-6.1+00-7.2+00-8.6+00-1.1+01-1.5+01-2.5+01 0.0    0.0   -2.5+01-1.5+01-1.1+01-8.4+00-6.9+00-5.9+00-5.0+00
-4.7+00-5.2+00-6.0+00-6.9+00-8.2+00-1.0+01-1.3+01-1.7+01-2.5+01-2.5+01-1.7+01-1.3+01-1.0+01-8.1+00-6.7+00-5.7+00-4.9+00
-4.6+00-5.1+00-5.7+00-6.5+00-7.6+00-9.1+00-1.1+01-1.3+01-1.5+01-1.5+01-1.3+01-1.1+01-9.0+00-7.4+00-6.3+00-5.4+00-4.7+00
-4.4+00-4.8+00-5.4+00-6.1+00-6.9+00-7.9+00-9.1+00-1.0+01-1.1+01-1.1+01-1.0+01-9.0+00-7.8+00-6.7+00-5.8+00-5.1+00-4.5+00
-4.2+00-4.6+00-5.0+00-5.6+00-6.2+00-6.9+00-7.5+00-8.1+00-8.5+00-8.4+00-8.1+00-7.4+00-6.7+00-6.0+00-5.3+00-4.7+00-4.2+00
-3.9+00-4.3+00-4.6+00-5.1+00-5.5+00-6.0+00-6.4+00-6.8+00-6.9+00-6.9+00-6.7+00-6.3+00-5.8+00-5.3+00-4.8+00-4.3+00-4.0+00
-3.7+00-4.0+00-4.3+00-4.6+00-4.9+00-5.2+00-5.5+00-5.8+00-5.9+00-5.9+00-5.7+00-5.4+00-5.1+00-4.7+00-4.3+00-4.0+00-3.7+00
-3.5+00-3.7+00-3.9+00-4.2+00-4.4+00-4.6+00-4.8+00-5.0+00-5.0+00-5.0+00-4.9+00-4.7+00-4.5+00-4.2+00-4.0+00-3.7+00-3.5+00
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P(I,J,10, 1)

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-3.5+00-3.7+00-3.9+00-4.1+00-4.3+00-4.5+00-4.7+00-4.8+00-4.8+00-4.6+00-4.7+00-4.5+00-4.3+00-4.1+00-3.9+00-3.7+00-3.5+00
-3.7+00-3.9+00-4.2+00-4.5+00-4.8+00-5.0+00-5.2+00-5.3+00-5.3+00-5.3+00-5.2+00-5.0+00-4.8+00-4.5+00-4.2+00-4.0+00-3.7+00
-3.9+00-4.2+00-4.6+00-4.9+00-5.2+00-5.5+00-5.8+00-6.0+00-6.1+00-6.1+00-5.7 00-5.7+00-5.4+00-5.0+00-4.6+00-4.2+00-3.9+00
-4.1+00-4.5+00-4.9+00-5.1+00-5.7+00-6.2+00-6.6+00-7.0+00-7.2+00-7.1+00-6.9+00-6.5+00-6.0+00-5.5+00-5.0+00-4.6+00-4.2+00
-4.3+00-4.8+00-5.2+00-5.7+00-6.3+00-7.0+00-7.7+00-8.3+00-8.6+00-8.6+00-8.2+00-7.6+00-6.9+00-6.2+00-5.5+00-4.9+00-4.4+00
-4.5+00-5.0+00-5.5+00-6.2+00-7.0+00-8.1+00-9.2+00-1.0+01-1.1+01-1.1+01-1.0+01-9.1+00-7.9+00-6.8+00-6.0+00-5.2+00-4.6+00
-4.7+00-5.2+00-5.8+00-6.6+00-7.7+00-9.2+00-1.1+01-1.3+01-1.5+01-1.5+01-1.3+01-1.1+01-9.1+00-7.5+00-6.4+00-5.5+00-4.8+00
-4.8+00-5.3+00-6.0+00-7.0+00-8.3+00-1.0+01-1.3+01-1.8+01-2.5+01-2.5+01-1.7+01-1.3+01-1.0+01-8.1+00-6.7+00-5.7+00-5.0+00
-4.8+00-5.3+00-6.1+00-7.2+00-8.6+00-1.1+01-1.5+01-2.5+01 0.0    0.0   -2.5+01-1.5+01-1.1+01-8.4+00-6.9+00-5.9+00-5.0+00
-4.8+00-5.3+00-6.1+00-7.1+00-8.6+00-1.1+01-1.5+01-2.5+01 0.0    0.0   -2.5+01-1.5+01-1.1+01-8.4+00-6.9+00-5.8+00-5.0+00
-4.7+00-5.2+00-5.9+00-6.9+00-8.2+00-1.0+01-1.3+01-1.7+01-2.5+01-2.5+01-1.7+01-1.3+01-1.0+01-8.0+00-6.7+00-5.7+00-4.9+00
-4.5+00-5.0+00-5.7+00-6.5+00-7.6+00-9.1+00-1.1+01-1.3+01-1.5+01-1.5+01-1.3+01-1.1+01-9.0+00-7.4+00-6.3+00-5.4+00-4.7+00
-4.3+00-4.8+00-5.4+00-6.2+00-6.9+00-7.9+00-9.1+00-1.0+01-1.1+01-1.1+01-1.0+01-9.0+00-7.7+00-6.7+00-5.8+00-5.1+00-4.5+00
-4.1+00-4.5+00-5.0+00-5.5+00-6.2+00-6.8+00-7.5+00-8.1+00-8.4+00-8.4+00-8.0+00-7.4+00-6.7+00-6.0+00-5.3+00-4.7+00-4.2+00
-3.9+00-4.2+00-4.6+00-5.0+00-5.5+00-6.0+00-6.4+00-6.7+00-6.9+00-6.9+00-6.7+00-6.3+00-5.8+00-5.3+00-4.8+00-4.3+00-3.9+00
-3.7+00-4.0+00-4.2+00-4.6+00-4.9+00-5.2+00-5.5+00-5.7+00-5.9+00-5.8+00-5.7+00-5.4+00-5.1+00-4.7+00-4.3+00-4.0+00-3.7+00
-3.5+00-3.7+00-3.9+00-4.2+00-4.4+00-4.6+00-4.8+00-5.0+00-5.0+00-5.0+00-4.9+00-4.7+00-4.5+00-4.2+00-4.0+00-3.7+00-3.5+00
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P(I,J,11, 1)

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-3.4+00-3.6+00-3.9+00-4.1+00-4.3+00-4.4+00-4.6+00-4.7+00-4.7+00-4.7+00-4.6+00-4.4+00-4.3+00-4.1+00-3.9+00-3.6+00-3.4+00
-3.6+00-3.9+00-4.2+00-4.4+00-4.7+00-4.9+00-5.1+00-5.2+00-5.2+00-5.2+00-5.1+00-4.9+00-4.7+00-4.4+00-4.2+00-3.9+00-3.6+00
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-3.9+00-4.2+00-4.5+00-4.8+00-5.1+00-5.4+00-5.7+00-5.9+00-6.0+00-5.9+00-5.8+00-5.6+00-5.2+00-4.9+00-4.5+00-4.2+00-3.9+00
-4.1+00-4.4+00-4.8+00-5.2+00-5.6+00-6.0+00-6.4+00-6.8+00-6.9+00-6.9+00-6.7+00-6.3+00-5.9+00-5.4+00-4.9+00-4.5+00-4.1+00
-4.3+00-4.7+00-5.1+00-5.6+00-6.2+00-6.8+00-7.4+00-8.0+00-8.2+00-8.2+00-7.9+00-7.3+00-6.7+00-6.0+00-5.4+00-4.8+00-4.3+00
-4.4+00-4.9+00-5.4+00-6.0+00-6.8+00-7.8+00-8.7+00-9.7+00-1.0+01-1.0+01-9.6+00-8.5+00-7.6+00-6.6+00-5.6+00-5.1+00-4.5+00
-4.6+00-5.1+00-5.7+00-6.4+00-7.4+00-8.7+00-1.0+01-1.2+01-1.3+01-1.3+01-1.2+01-1.0+01-8.6+00-7.3+00-6.2+00-5.4+00-4.7+00
-4.7+00-5.2+00-5.9+00-6.8+00-8.0+00-9.7+00-1.2+01-1.5+01-1.7+01-1.7+01-1.5+01-1.2+01-9.5+00-7.6+00-6.5+00-5.6+00-4.8+00
-4.7+00-5.2+00-6.0+00-6.9+00-8.2+00-1.0+01-1.3+01-1.7+01-2.5+01-2.5+01-1.7+01-1.3+01-1.0+01-8.1+00-6.7+00-5.7+00-4.9+00
-4.7+00-5.2+00-5.9+00-6.9+00-8.2+00-1.0+01-1.3+01-1.7+01-2.5+01-2.5+01-1.7+01-1.3+01-1.0+01-8.0+00-6.7+00-5.7+00-4.9+00
-4.6+00-5.1+00-5.8+00-6.7+00-7.9+00-9.6+00-1.2+01-1.5+01-1.7+01-1.7+01-1.5+01-1.2+01-9.5+00-7.7+00-6.5+00-5.5+00-4.8+00
-4.4+00-4.9+00-5.6+00-6.3+00-7.3+00-8.6+00-1.0+01-1.2+01-1.3+01-1.3+01-1.2+01-1.0+01-8.5+00-7.1+00-6.1+00-5.3+00-4.6+00
-4.3+00-4.7+00-5.2+00-5.9+00-6.7+00-7.6+00-8.6+00-9.5+00-1.0+01-1.0+01-9.5+00-8.5+00-7.4+00-6.5+00-5.6+00-4.9+00-4.4+00
-4.1+00-4.4+00-4.9+00-5.4+00-6.0+00-6.6+00-7.3+00-7.8+00-8.1+00-8.0+00-7.7+00-7.1+00-6.5+00-5.8+00-5.1+00-4.6+00-4.1+00
-3.9+00-4.2+00-4.5+00-4.9+00-5.4+00-5.8+00-6.2+00-6.5+00-6.7+00-6.7+00-6.5+00-6.1+00-5.6+00-5.1+00-4.7+00-4.2+00-3.9+00
-3.6+00-3.9+00-4.2+00-4.5+00-4.8+00-5.1+00-5.4+00-5.6+00-5.7+00-5.7+00-5.5+00-5.3+00-4.9+00-4.6+00-4.2+00-3.9+00-3.6+00
-3.4+00-3.6+00-3.9+00-4.1+00-4.3+00-4.5+00-4.7+00-4.8+00-4.9+00-4.9+00-4.8+00-4.6+00-4.4+00-4.1+00-3.9+00-3.6+00-3.4+00
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P(I,J,12, 1)

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-3.4+00-3.6+00-3.8+00-4.0+00-4.2+00-4.3+00-4.4+00-4.5+00-4.6+00-4.5+00-4.5+00-4.3+00-4.2+00-4.0+00-3.8+00-3.6+00-3.4+00
-3.6+00-3.8+00-4.1+00-4.3+00-4.5+00-4.7+00-4.9+00-5.0+00-5.1+00-5.0+00-4.9+00-4.8+00-4.6+00-4.3+00-4.1+00-3.8+00-3.6+00
-3.8+00-4.1+00-4.3+00-4.7+00-4.9+00-5.2+00-5.4+00-5.6+00-5.7+00-5.7+00-5.6+00-5.3+00-5.0+00-4.7+00-4.4+00-4.1+00-3.8+00
-4.0+00-4.3+00-4.7+00-5.0+00-5.4+00-5.8+00-6.1+00-6.4+00-6.5+00-6.5+00-6.3+00-6.0+00-5.6+00-5.2+00-4.7+00-4.3+00-4.0+00
-4.2+00-4.5+00-4.9+00-5.4+00-5.9+00-6.4+00-7.0+00-7.4+00-7.6+00-7.6+00-7.3+00-6.9+00-6.3+00-5.7+00-5.1+00-4.6+00-4.2+00
-4.3+00-4.7+00-5.2+00-5.8+00-6.4+00-7.2+00-8.0+00-8.7+00-9.1+00-9.1+00-8.6+00-7.9+00-7.1+00-6.3+00-5.5+00-4.9+00-4.4+00
-4.4+00-4.9+00-5.4+00-6.1+00-7.0+00-8.0+00-9.2+00-1.0+01-1.1+01-1.1+01-1.0+01-9.1+00-7.9+00-6.8+00-5.9+00-5.2+00-4.6+00
-4.5+00-5.0+00-5.6+00-6.4+00-7.4+00-8.7+00-1.0+01-1.2+01-1.3+01-1.3+01-1.2+01-1.0+01-8.6+00-7.2+00-6.2+00-5.3+00-4.7+00
-4.6+00-5.1+00-5.7+00-6.5+00-7.6+00-9.1+00-1.1+01-1.3+01-1.5+01-1.5+01-1.3+01-1.1+01-9.0+00-7.4+00-6.3+00-5.4+00-4.7+00
-4.5+00-5.0+00-5.7+00-6.5+00-7.6+00-9.1+00-1.1+01-1.3+01-1.5+01-1.5+01-1.3+01-1.1+01-9.0+00-7.4+00-6.3+00-5.4+00-4.7+00
-4.5+00-4.9+00-5.6+00-6.3+00-7.3+00-8.6+00-1.0+01-1.2+01-1.3+01-1.3+01-1.2+01-1.0+01-8.5+00-7.2+00-6.1+00-5.3+00-4.6+00
-4.3+00-4.8+00-5.3+00-6.0+00-6.9+00-7.9+00-9.1+00-1.0+01-1.1+01-1.1+01-1.0+01-9.0+00-7.8+00-6.7+00-5.8+00-5.0+00-4.4+00
-4.2+00-4.6+00-5.0+00-5.6+00-6.3+00-7.1+00-7.9+00-8.6+00-9.0+00-9.0+00-8.5+00-7.8+00-6.9+00-6.1+00-5.4+00-4.7+00-4.2+00
-4.0+00-4.3+00-4.7+00-5.2+00-5.7+00-6.3+00-6.8+00-7.2+00-7.4+00-7.4+00-7.2+00-6.7+00-6.1+00-5.5+00-4.9+00-4.4+00-4.0+00
-3.8+00-4.1+00-4.4+00-4.7+00-5.1+00-5.5+00-5.9+00-6.2+00-6.3+00-6.3+00-6.1+00-5.8+00-5.4+00-4.9+00-4.5+00-4.1+00-3.8+00
-3.6+00-3.8+00-4.1+00-4.3+00-4.6+00-4.9+00-5.2+00-5.3+00-5.4+00-5.4+00-5.3+00-5.0+00-4.7+00-4.4+00-4.1+00-3.8+00-3.6+00
-3.4+00-3.6+00-3.8+00-4.0+00-4.2+00-4.4+00-4.6+00-4.7+00-4.7+00-4.7+00-4.6+00-4.4+00-4.2+00-4.0+00-3.8+00-3.6+00-3.4+00
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P(I,J,13, 1)

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-3.3+00-3.5+00-3.7+00-3.8+00-4.0+00-4.2+00-4.3+00-4.3+00-4.4+00-4.3+00-4.3+00-4.2+00-4.0+00-3.8+00-3.7+00-3.5+00-3.3+00
-3.5+00-3.7+00-3.9+00-4.1+00-4.4+00-4.5+00-4.7+00-4.8+00-4.8+00-4.8+00-4.7+00-4.6+00-4.4+00-4.2+00-3.9+00-3.7+00-3.5+00
-3.7+00-3.9+00-4.2+00-4.5+00-4.7+00-5.0+00-5.2+00-5.3+00-5.4+00-5.4+00-5.2+00-5.0+00-4.8+00-4.5+00-4.2+00-3.9+00-3.7+00
-3.8+00-4.1+00-4.5+00-4.8+00-5.1+00-5.4+00-5.7+00-6.0+00-6.1+00-6.0+00-5.9+00-5.6+00-5.3+00-4.9+00-4.5+00-4.2+00-3.8+00
-4.0+00-4.4+00-4.7+00-5.1+00-5.5+00-6.0+00-6.4+00-6.7+00-6.9+00-6.9+00-6.7+00-6.3+00-5.8+00-5.3+00-4.9+00-4.4+00-4.0+00
-4.2+00-4.5+00-5.0+00-5.4+00-6.0+00-6.6+00-7.2+00-7.7+00-7.9+00-7.9+00-7.6+00-7.1+00-6.4+00-5.8+00-5.2+00-4.7+00-4.2+00
-4.3+00-4.7+00-5.2+00-5.7+00-6.4+00-7.2+00-8.0+00-8.7+00-9.1+00-9.1+00-8.6+00-7.9+00-7.0+00-6.2+00-5.5+00-4.9+00-4.3+00
-4.3+00-4.8+00-5.3+00-6.0+00-6.7+00-7.7+00-8.7+00-9.6+00-1.0+01-1.0+01-9.5+00-8.6+00-7.5+00-6.5+00-5.7+00-5.0+00-4.4+00
-4.4+00-4.8+00-5.4+00-6.1+00-6.9+00-7.9+00-9.1+00-1.0+01-1.1+01-1.1+01-1.0+01-9.0+00-7.8+00-6.7+00-5.8+00-5.1+00-4.5+00
-4.3+00-4.8+00-5.4+00-6.0+00-6.9+00-7.9+00-9.1+00-1.0+01-1.1+01-1.1+01-1.0+01-9.0+00-7.7+00-6.7+00-5.8+00-5.1+00-4.5+00
-4.3+00-4.7+00-5.2+00-5.9+00-6.7+00-7.6+00-8.6+00-9.5+00-1.0+01-1.0+01-9.5+00-8.5+00-7.4+00-6.5+00-5.6+00-4.9+00-4.4+00
-4.2+00-4.6+00-5.0+00-5.6+00-6.3+00-7.1+00-7.9+00-8.6+00-9.0+00-9.0+00-8.5+00-7.8+00-6.9+00-6.1+00-5.4+00-4.7+00-4.2+00
-4.0+00-4.4+00-4.8+00-5.3+00-5.9+00-6.4+00-7.0+00-7.5+00-7.8+00-7.7+00-7.4+00-6.9+00-6.3+00-5.6+00-5.0+00-4.5+00-4.1+00
-3.8+00-4.2+00-4.5+00-4.9+00-5.3+00-5.8+00-6.2+00-6.5+00-6.7+00-6.7+00-6.5+00-6.1+00-5.6+00-5.1+00-4.6+00-4.2+00-3.9+00
-3.7+00-3.9+00-4.2+00-4.5+00-4.9+00-5.2+00-5.5+00-5.7+00-5.8+00-5.8+00-5.6+00-5.4+00-5.0+00-4.6+00-4.3+00-4.0+00-3.7+00
-3.5+00-3.7+00-3.9+00-4.2+00-4.4+00-4.7+00-4.9+00-5.0+00-5.1+00-5.1+00-5.0+00-4.7+00-4.5+00-4.2+00-4.0+00-3.7+00-3.5+00
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-3.3+00-3.5+00-3.7+00-3.8+00-4.0+00-4.2+00-4.3+00-4.4+00-4.5+00-4.5+00-4.4+00-4.2+00-4.1+00-3.9+00-3.7+00-3.5+00-3.3+00

P(I,J,14, I)

 -3.2+00-3.4+00-3.5+00-3.7+00-3.8+00-4.0+00-4.1+00-4.1+00-4.2+00-4.1+00-4.1+00-4.0+00-3.8+00-3.7+00-3.5+00-3.4+00-3.2+00
 -3.4+00-3.6+00-3.8+00-4.0+00-4.1+00-4.3+00-4.4+00-4.5+00-4.6+00-4.5+00-4.5+00-4.3+00-4.2+00-4.0+00-3.8+00-3.6+00-3.4+00
 -3.5+00-3.8+00-4.0+00-4.2+00-4.5+00-4.7+00-4.8+00-5.0+00-5.0+00-5.0+00-4.9+00-4.7+00-4.5+00-4.3+00-4.0+00-3.8+00-3.5+00
 -3.7+00-4.0+00-4.2+00-4.5+00-4.8+00-5.1+00-5.3+00-5.5+00-5.6+00-5.5+00-5.4+00-5.2+00-4.9+00-4.6+00-4.3+00-4.0+00-3.7+00
 -3.8+00-4.1+00-4.5+00-4.8+00-5.2+00-5.5+00-5.8+00-6.1+00-6.2+00-6.2+00-6.0+00-5.7+00-5.3+00-4.9+00-4.5+00-4.2+00-3.9+00
 -4.0+00-4.3+00-4.7+00-5.1+00-5.5+00-5.9+00-6.4+00-6.7+00-6.9+00-6.8+00-6.6+00-6.3+00-5.8+00-5.3+00-4.8+00-4.4+00-4.0+00
 -4.1+00-4.4+00-4.8+00-5.3+00-5.8+00-6.4+00-6.9+00-7.3+00-7.6+00-7.5+00-7.3+00-6.8+00-6.2+00-5.6+00-5.0+00-4.5+00-4.1+00
 -4.1+00-4.5+00-5.0+00-5.5+00-6.1+00-6.7+00-7.3+00-7.8+00-8.1+00-8.1+00-7.6+00-7.2+00-6.5+00-5.9+00-5.2+00-4.7+00-4.2+00
 -4.2+00-4.6+00-5.0+00-5.6+00-6.2+00-6.9+00-7.6+00-8.1+00-8.5+00-8.5+00-8.1+00-7.5+00-6.7+00-6.0+00-5.3+00-4.7+00-4.2+00
 -4.1+00-4.5+00-5.0+00-5.5+00-6.2+00-6.8+00-7.5+00-8.1+00-8.5+00-8.4+00-8.1+00-7.4+00-6.7+00-6.0+00-5.3+00-4.7+00-4.2+00
 -4.1+00-4.5+00-4.9+00-5.4+00-6.0+00-6.6+00-7.3+00-7.8+00-8.1+00-8.1+00-7.7+00-7.2+00-6.5+00-5.8+00-5.1+00-4.6+00-4.1+00
 -4.0+00-4.3+00-4.7+00-5.2+00-5.7+00-6.3+00-6.8+00-7.2+00-7.5+00-7.4+00-7.2+00-6.7+00-6.1+00-5.5+00-4.9+00-4.4+00-4.0+00
 -3.8+00-4.2+00-4.5+00-4.9+00-5.3+00-5.8+00-6.2+00-6.5+00-6.7+00-6.7+00-6.5+00-6.1+00-5.6+00-5.1+00-4.7+00-4.2+00-3.9+00
 -3.7+00-4.0+00-4.3+00-4.6+00-4.9+00-5.3+00-5.6+00-5.9+00-6.0+00-6.0+00-5.8+00-5.5+00-5.1+00-4.7+00-4.3+00-4.0+00-3.7+00
 -3.5+00-3.8+00-4.0+00-4.3+00-4.5+00-4.8+00-5.0+00-5.2+00-5.3+00-5.3+00-5.1+00-4.9+00-4.7+00-4.3+00-4.1+00-3.8+00-3.5+00
 -3.4+00-3.6+00-3.8+00-4.0+00-4.2+00-4.4+00-4.5+00-4.7+00-4.7+00-4.7+00-4.6+00-4.4+00-4.2+00-4.0+00-3.8+00-3.6+00-3.4+00
 -3.2+00-3.4+00-3.5+00-3.7+00-3.9+00-4.0+00-4.1+00-4.2+00-4.2+00-4.2+00-4.1+00-4.0+00-3.9+00-3.7+00-3.5+00-3.4+00-3.2+00

P(I,J,15, I)

 -3.1+00-3.2+00-3.4+00-3.5+00-3.7+00-3.8+00-3.9+00-3.9+00-3.9+00-3.9+00-3.9+00-3.8+00-3.7+00-3.5+00-3.4+00-3.2+00-3.1+00
 -3.2+00-3.4+00-3.6+00-3.8+00-3.9+00-4.1+00-4.2+00-4.2+00-4.3+00-4.2+00-4.2+00-4.1+00-3.9+00-3.8+00-3.6+00-3.4+00-3.2+00
 -3.4+00-3.6+00-3.8+00-4.0+00-4.2+00-4.4+00-4.5+00-4.6+00-4.6+00-4.6+00-4.5+00-4.4+00-4.2+00-4.0+00-3.8+00-3.6+00-3.4+00
 -3.5+00-3.8+00-4.0+00-4.2+00-4.5+00-4.7+00-4.9+00-5.0+00-5.1+00-5.0+00-4.9+00-4.8+00-4.5+00-4.3+00-4.0+00-3.8+00-3.5+00
 -3.7+00-3.9+00-4.2+00-4.5+00-4.8+00-5.0+00-5.3+00-5.4+00-5.5+00-5.5+00-5.4+00-5.1+00-4.9+00-4.5+00-4.2+00-3.9+00-3.7+00
 -3.8+00-4.1+00-4.4+00-4.7+00-5.0+00-5.4+00-5.7+00-5.9+00-6.0+00-6.0+00-5.8+00-5.5+00-5.2+00-4.8+00-4.4+00-4.1+00-3.8+00
 -3.9+00-4.2+00-4.5+00-4.9+00-5.3+00-5.7+00-6.0+00-6.3+00-6.4+00-6.4+00-6.2+00-5.9+00-5.5+00-5.0+00-4.6+00-4.2+00-3.9+00
 -3.9+00-4.2+00-4.6+00-5.0+00-5.4+00-5.9+00-6.3+00-6.6+00-6.8+00-6.6+00-6.5+00-6.2+00-5.7+00-5.2+00-4.7+00-4.3+00-3.9+00
 -3.9+00-4.3+00-4.6+00-5.1+00-5.5+00-6.0+00-6.4+00-6.8+00-7.0+00-6.9+00-6.7+00-6.3+00-5.8+00-5.3+00-4.8+00-4.3+00-4.0+00
 -3.9+00-4.2+00-4.6+00-5.0+00-5.5+00-6.0+00-6.4+00-6.8+00-6.9+00-6.9+00-6.7+00-6.3+00-5.8+00-5.3+00-4.8+00-4.3+00-3.9+00
 -3.9+00-4.2+00-4.5+00-4.9+00-5.4+00-5.8+00-6.2+00-6.5+00-6.7+00-6.7+00-6.5+00-6.1+00-5.7+00-5.2+00-4.7+00-4.2+00-3.9+00
 -3.8+00-4.1+00-4.4+00-4.8+00-5.1+00-5.5+00-5.9+00-6.2+00-6.3+00-6.3+00-6.1+00-5.8+00-5.4+00-4.9+00-4.5+00-4.1+00-3.8+00
 -3.7+00-3.9+00-4.2+00-4.5+00-4.9+00-5.2+00-5.5+00-5.7+00-5.8+00-5.8+00-5.7+00-5.4+00-5.0+00-4.7+00-4.3+00-4.0+00-3.7+00
 -3.5+00-3.8+00-4.0+00-4.3+00-4.5+00-4.8+00-5.0+00-5.2+00-5.3+00-5.3+00-5.2+00-4.9+00-4.7+00-4.4+00-4.1+00-3.8+00-3.5+00
 -3.4+00-3.6+00-3.8+00-4.0+00-4.2+00-4.4+00-4.6+00-4.7+00-4.8+00-4.8+00-4.7+00-4.5+00-4.3+00-4.1+00-3.8+00-3.6+00-3.4+00
 -3.2+00-3.4+00-3.6+00-3.8+00-3.9+00-4.1+00-4.2+00-4.3+00-4.3+00-4.3+00-4.2+00-4.1+00-4.0+00-3.8+00-3.6+00-3.4+00-3.2+00
 -3.1+00-3.2+00-3.4+00-3.5+00-3.7+00-3.8+00-3.9+00-3.9+00-4.0+00-3.9+00-3.9+00-3.8+00-3.7+00-3.5+00-3.4+00-3.2+00-3.1+00

P(I,J,16, I)

 -3.0+00-3.1+00-3.2+00-3.4+00-3.5+00-3.6+00-3.6+00-3.7+00-3.7+00-3.7+00-3.6+00-3.6+00-3.5+00-3.4+00-3.2+00-3.1+00-3.0+00
 -3.1+00-3.3+00-3.4+00-3.6+00-3.7+00-3.8+00-3.9+00-4.0+00-4.0+00-4.0+00-3.9+00-3.8+00-3.7+00-3.6+00-3.4+00-3.3+00-3.1+00
 -3.2+00-3.4+00-3.6+00-3.8+00-3.9+00-4.1+00-4.2+00-4.3+00-4.3+00-4.3+00-4.2+00-4.1+00-3.9+00-3.8+00-3.6+00-3.4+00-3.2+00
 -3.4+00-3.6+00-3.8+00-4.0+00-4.2+00-4.3+00-4.5+00-4.6+00-4.6+00-4.6+00-4.5+00-4.4+00-4.2+00-4.0+00-3.8+00-3.6+00-3.4+00
 -3.5+00-3.7+00-3.9+00-4.2+00-4.4+00-4.6+00-4.8+00-4.9+00-4.9+00-4.9+00-4.8+00-4.6+00-4.4+00-4.2+00-3.9+00-3.7+00-3.5+00
 -3.6+00-3.8+00-4.1+00-4.3+00-4.6+00-4.8+00-5.0+00-5.2+00-5.3+00-5.2+00-5.1+00-4.9+00-4.7+00-4.4+00-4.1+00-3.8+00-3.6+00
 -3.6+00-3.9+00-4.2+00-4.5+00-4.8+00-5.0+00-5.3+00-5.5+00-5.6+00-5.5+00-5.4+00-5.2+00-4.9+00-4.5+00-4.2+00-3.9+00-3.6+00
 -3.7+00-4.0+00-4.3+00-4.6+00-4.9+00-5.2+00-5.5+00-5.7+00-5.8+00-5.8+00-5.6+00-5.3+00-5.0+00-4.7+00-4.3+00-4.0+00-3.7+00
 -3.7+00-4.0+00-4.3+00-4.6+00-4.9+00-5.3+00-5.6+00-5.8+00-5.9+00-5.9+00-5.7+00-5.4+00-5.1+00-4.7+00-4.3+00-4.0+00-3.7+00
 -3.7+00-4.0+00-4.3+00-4.6+00-4.9+00-5.2+00-5.5+00-5.8+00-5.9+00-5.8+00-5.7+00-5.4+00-5.1+00-4.7+00-4.3+00-4.0+00-3.7+00
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-3.6+00-3.9+00-4.2+00-4.5+00-4.8+00-5.1+00-5.4+00-5.6+00-5.7+00-5.7+00-5.5+00-5.3+00-5.0+00-4.6+00-4.2+00-3.9+00-3.7+00
-3.6+00-3.8+00-4.1+00-4.4+00-4.6+00-4.9+00-5.2+00-5.3+00-5.4+00-5.4+00-5.3+00-5.0+00-4.8+00-4.4+00-4.1+00-3.8+00-3.6+00
-3.5+00-3.7+00-3.9+00-4.2+00-4.4+00-4.7+00-4.9+00-5.0+00-5.1+00-5.1+00-5.0+00-4.8+00-4.5+00-4.2+00-4.0+00-3.7+00-3.5+00
-3.4+00-3.6+00-3.8+00-4.0+00-4.2+00-4.4+00-4.5+00-4.7+00-4.7+00-4.7+00-4.6+00-4.4+00-4.2+00-4.0+00-3.8+00-3.6+00-3.4+00
-3.2+00-3.4+00-3.6+00-3.8+00-3.9+00-4.1+00-4.2+00-4.3+00-4.3+00-4.3+00-4.2+00-4.1+00-4.0+00-3.8+00-3.6+00-3.4+00-3.2+00
-3.1+00-3.3+00-3.4+00-3.6+00-3.7+00-3.8+00-3.9+00-4.0+00-4.0+00-4.0+00-3.9+00-3.8+00-3.7+00-3.6+00-3.4+00-3.3+00-3.1+00
-3.0+00-3.1+00-3.2+00-3.4+00-3.5+00-3.6+00-3.6+00-3.7+00-3.7+00-3.7+00-3.6+00-3.5+00-3.4+00-3.2+00-3.1+00-3.0+00
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P(I,J,17, 1)

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-2.8+00-3.0+00-3.1+00-3.2+00-3.3+00-3.4+00-3.4+00-3.5+00-3.5+00-3.5+00-3.4+00-3.4+00-3.3+00-3.2+00-3.1+00-3.0+00-2.8+00
-3.0+00-3.1+00-3.2+00-3.4+00-3.5+00-3.6+00-3.6+00-3.7+00-3.7+00-3.7+00-3.6+00-3.6+00-3.5+00-3.4+00-3.2+00-3.1+00-3.0+00
-3.1+00-3.2+00-3.4+00-3.5+00-3.7+00-3.8+00-3.9+00-3.9+00-3.9+00-3.9+00-3.9+00-3.8+00-3.7+00-3.5+00-3.4+00-3.2+00-3.1+00
-3.2+00-3.4+00-3.5+00-3.7+00-3.9+00-4.0+00-4.1+00-4.2+00-4.2+00-4.2+00-4.1+00-4.0+00-3.9+00-3.7+00-3.5+00-3.4+00-3.2+00
-3.3+00-3.5+00-3.7+00-3.9+00-4.0+00-4.2+00-4.3+00-4.4+00-4.4+00-4.4+00-4.3+00-4.2+00-4.0+00-3.9+00-3.7+00-3.5+00-3.3+00
-3.4+00-3.6+00-3.8+00-4.0+00-4.2+00-4.4+00-4.5+00-4.6+00-4.7+00-4.6+00-4.5+00-4.4+00-4.2+00-4.0+00-3.8+00-3.6+00-3.4+00
-3.4+00-3.6+00-3.9+00-4.1+00-4.3+00-4.5+00-4.7+00-4.8+00-4.9+00-4.8+00-4.7+00-4.6+00-4.4+00-4.1+00-3.9+00-3.7+00-3.4+00
-3.5+00-3.7+00-3.9+00-4.2+00-4.4+00-4.6+00-4.8+00-4.9+00-5.0+00-5.0+00-4.9+00-4.7+00-4.5+00-4.2+00-4.0+00-3.7+00-3.5+00
-3.5+00-3.7+00-3.9+00-4.2+00-4.4+00-4.7+00-4.9+00-5.0+00-5.1+00-5.1+00-4.9+00-4.7+00-4.5+00-4.2+00-4.0+00-3.7+00-3.5+00
-3.5+00-3.7+00-3.9+00-4.2+00-4.4+00-4.6+00-4.8+00-5.0+00-5.1+00-5.0+00-4.9+00-4.7+00-4.5+00-4.2+00-4.0+00-3.7+00-3.5+00
-3.4+00-3.6+00-3.9+00-4.1+00-4.3+00-4.5+00-4.7+00-4.9+00-4.9+00-4.9+00-4.8+00-4.6+00-4.4+00-4.1+00-3.9+00-3.7+00-3.4+00
-3.4+00-3.6+00-3.8+00-4.0+00-4.2+00-4.4+00-4.6+00-4.7+00-4.7+00-4.7+00-4.6+00-4.5+00-4.3+00-4.0+00-3.8+00-3.6+00-3.4+00
-3.3+00-3.5+00-3.7+00-3.9+00-4.0+00-4.2+00-4.4+00-4.5+00-4.5+00-4.5+00-4.4+00-4.3+00-4.1+00-3.9+00-3.7+00-3.5+00-3.3+00
-3.2+00-3.4+00-3.5+00-3.7+00-3.9+00-4.0+00-4.1+00-4.2+00-4.2+00-4.2+00-4.1+00-4.0+00-3.9+00-3.7+00-3.5+00-3.4+00-3.2+00
-3.1+00-3.2+00-3.4+00-3.5+00-3.7+00-3.8+00-3.9+00-4.0+00-4.0+00-4.0+00-3.9+00-3.8+00-3.7+00-3.5+00-3.4+00-3.2+00-3.1+00
-3.0+00-3.1+00-3.2+00-3.4+00-3.5+00-3.6+00-3.7+00-3.7+00-3.7+00-3.7+00-3.6+00-3.5+00-3.4+00-3.2+00-3.1+00-3.0+00
-2.8+00-3.0+00-3.1+00-3.2+00-3.3+00-3.4+00-3.4+00-3.5+00-3.5+00-3.5+00-3.4+00-3.4+00-3.3+00-3.2+00-3.1+00-3.0+00-2.8+00
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P(I,J, 1, 2)

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-1.4+00-1.5+00-1.5+00-1.6+00-1.6+00-1.7+00-1.7+00-1.7+00-1.7+00-1.7+00-1.7+00-1.6+00-1.6+00-1.5+00-1.5+00-1.4+00
-1.5+00-1.5+00-1.6+00-1.7+00-1.7+00-1.8+00-1.8+00-1.8+00-1.8+00-1.8+00-1.8+00-1.8+00-1.7+00-1.7+00-1.6+00-1.5+00-1.5+00
-1.5+00-1.6+00-1.7+00-1.8+00-1.8+00-1.9+00-1.9+00-2.0+00-2.0+00-2.0+00-1.9+00-1.9+00-1.8+00-1.8+00-1.7+00-1.6+00-1.5+00
-1.6+00-1.7+00-1.8+00-1.9+00-1.9+00-2.0+00-2.0+00-2.1+00-2.1+00-2.1+00-2.0+00-2.0+00-1.9+00-1.8+00-1.8+00-1.7+00-1.6+00
-1.6+00-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.1+00-2.2+00-2.2+00-2.2+00-2.1+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00-1.6+00
-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.2+00-2.2+00-2.3+00-2.3+00-2.3+00-2.2+00-2.2+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00
-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.2+00-2.3+00-2.4+00-2.4+00-2.4+00-2.3+00-2.2+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00
-1.7+00-1.8+00-2.0+00-2.1+00-2.2+00-2.3+00-2.4+00-2.4+00-2.4+00-2.4+00-2.4+00-2.3+00-2.2+00-2.1+00-2.0+00-1.8+00-1.7+00
-1.7+00-1.8+00-2.0+00-2.1+00-2.2+00-2.3+00-2.4+00-2.4+00-2.5+00-2.4+00-2.4+00-2.3+00-2.2+00-2.1+00-2.0+00-1.8+00-1.7+00
-1.7+00-1.8+00-2.0+00-2.1+00-2.2+00-2.3+00-2.4+00-2.4+00-2.4+00-2.4+00-2.4+00-2.3+00-2.2+00-2.1+00-2.0+00-1.8+00-1.7+00
-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.2+00-2.3+00-2.4+00-2.4+00-2.4+00-2.3+00-2.2+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00
-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.2+00-2.2+00-2.3+00-2.3+00-2.3+00-2.2+00-2.2+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00
-1.6+00-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.1+00-2.2+00-2.2+00-2.2+00-2.1+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00-1.6+00
-1.6+00-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.1+00-2.2+00-2.2+00-2.2+00-2.1+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00-1.6+00
-1.5+00-1.6+00-1.7+00-1.8+00-1.8+00-1.9+00-1.9+00-2.0+00-2.0+00-2.0+00-1.9+00-1.9+00-1.8+00-1.8+00-1.7+00-1.6+00-1.5+00
-1.5+00-1.5+00-1.6+00-1.7+00-1.7+00-1.8+00-1.8+00-1.8+00-1.8+00-1.8+00-1.8+00-1.8+00-1.7+00-1.7+00-1.6+00-1.5+00-1.5+00
-1.4+00-1.5+00-1.5+00-1.6+00-1.6+00-1.7+00-1.7+00-1.7+00-1.7+00-1.7+00-1.7+00-1.6+00-1.6+00-1.5+00-1.5+00-1.4+00
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P(I,J, 2, 2)

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-1.5+00-1.5+00-1.6+00-1.7+00-1.7+00-1.8+00-1.8+00-1.8+00-1.8+00-1.8+00-1.8+00-1.8+00-1.7+00-1.7+00-1.6+00-1.5+00-1.5+00
-1.5+00-1.6+00-1.7+00-1.8+00-1.8+00-1.9+00-1.9+00-2.0+00-2.0+00-2.0+00-1.9+00-1.9+00-1.8+00-1.8+00-1.7+00-1.6+00-1.5+00
-1.6+00-1.7+00-1.8+00-1.9+00-2.0+00-2.0+00-2.1+00-2.1+00-2.1+00-2.0+00-2.0+00-1.9+00-1.8+00-1.7+00-1.6+00
-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.2+00-2.2+00-2.3+00-2.3+00-2.3+00-2.2+00-2.2+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00-1.6+00
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-1.7+00-1.8+00-2.0+00-2.1+00-2.2+00-2.3+00-2.4+00-2.4+00-2.4+00-2.4+00-2.4+00-2.3+00-2.2+00-2.1+00-2.0+00-1.8+00-1.7+00
-1.8+00-1.9+00-2.0+00-2.2+00-2.3+00-2.4+00-2.5+00-2.6+00-2.6+00-2.6+00-2.5+00-2.4+00-2.3+00-2.2+00-2.0+00-1.9+00-1.8+00
-1.8+00-1.9+00-2.1+00-2.2+00-2.4+00-2.5+00-2.6+00-2.7+00-2.7+00-2.7+00-2.6+00-2.5+00-2.4+00-2.2+00-2.1+00-1.9+00-1.8+00
-1.8+00-2.0+00-2.1+00-2.3+00-2.4+00-2.6+00-2.7+00-2.8+00-2.8+00-2.8+00-2.7+00-2.6+00-2.4+00-2.3+00-2.1+00-2.0+00-1.8+00
-1.8+00-2.0+00-2.1+00-2.3+00-2.4+00-2.6+00-2.7+00-2.8+00-2.8+00-2.8+00-2.7+00-2.6+00-2.4+00-2.3+00-2.1+00-2.0+00-1.8+00
-1.8+00-2.0+00-2.1+00-2.3+00-2.4+00-2.6+00-2 7+00-2.8+00-2.8+00-2.8+00-2.7+00-2.6+00-2.4+00-2.3+00-2.1+00-2.0+00-1.8+00
-1.8+00-1.9+00-2.1+00-2.2+00-2.4+00-2.5+00-2.6+00-2.7+00-2.7+00-2.7+00-2.6+00-2.5+00-2.4+00-2.2+00-2.1+00-1.9+00-1.8+00
-1.8+00-1.9+00-2.0+00-2.2+00-2.3+00-2.4+00-2.5+00-2.6+00-2.6+00-2.6+00-2.5+00-2.4+00-2.3+00-2.2+00-2.0+00-1.9+00-1.8+00
-1.7+00-1.8+00-2.0+00-2.1+00-2.2+00-2.3+00-2.4+00-2.4+00-2.4+00-2.4+00-2.4+00-2.3+00-2.2+00-2.1+00-2.0+00-1.8+00-1.7+00
-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.2+00-2.2+00-2.3+00-2.3+00-2.3+00-2.2+00-2.2+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00
-1.6+00-1.7+00-1.8+00-1.9+00-2.0+00-2.0+00-2.1+00-2.1+00-2.1+00-2.1+00-2.1+00-2.0+00-2.0+00-1.9+00-1.8+00-1.7+00-1.6+00
-1.5+00-1.6+00-1.7+00-1.8+00-1.8+00-1.9+00-1.9+00-2.0+00-2.0+00-2.0+00-1.9+00-1.9+00-1.8+00-1.8+00-1.7+00-1.6+00-1.5+00
-1.5+00-1.5+00-1.6+00-1.7+00-1.7+00-1.8+00-1.8+00-1.8 00-1.8+00-1.8+00-1.8+00-1.8+00-1.7+00-1.7+00-1.6+00-1.5+00-1.5+00

P(I,J, 3, 2)

-1.5+00-1.6+00-1.7+00-1.8+00-1.8+00-1.9+00-1.9+00-2.0+00-2.0+00-2.0+00-1.9+00-1.9+00-1.8+00-1.8+00-1.7+00-1.6+00-1.5+00
-1.6+00-1.7+00-1.8+00-1.9+00-2.0+00-2.0+00-2.1+00-2.1+00-2.1+00-2.1+00-2.1+00-2.0+00-2.0+00-1.9+00-1.8+00-1.7+00-1.6+00
-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.2+00-2.3+00-2.3+00-2.3+00-2.3+00-2.3+00-2.2+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00
-1.8+00-1.9+00-2.0+00-2.1+00-2.3+00-2.4+00 2.5+00-2.5+00-2.5+00-2.5+00-2.5+00-2.4+00-2.3+00-2.1+00-2.0+00-1.9+00-1.8+00
-1.8+00-2.0+00-2.1+00-2.3+00-2.4+00-2.5+00-2.6+00-2.7+00-2.7+00-2.7+00-2.7+00-2.6+00-2.5+00-2.4+00-2.3+00-2.1+00-2.0+00-1.8+00
-1.9+00-2.0+00-2.2+00-2.4+00-2.5+00-2.   00-2.8+00-2.9+00-2.9+00-2.9+00-2.8+00-2.7+00-2.5+00-2.4+00-2.2+00-2.0+00-1.9+00
-1.9+00-2.1+00-2.3+00-2.5+00-2.6+00-2.8+00-3.0+00-3.1+00-3.1+00-3.1+00-3.0+00-2.8+00-2.6+00-2.5+00-2.3+00-2.1+00-1.9+00
-2.0+00-2.1+00-2.3+00-2.5+00-2.7+00-2.9+00-3.1+00 3.2+00-3.2+00-3.2+00-3.1+00-2.9+00-2.7+00-2.5+00-2.3+00-2.1+00-2.0+00
-2.0+00-2.1+00-2.3+00-2.5+00-2.7+00-2.9+00-3.1+00-3.2+00-3.3+00-3.2+00-3.1+00-2.9+00-2.7+00-2.5+00-2.3+00-2.1+00-2.0+00
-2.0+00-2.1+00-2.3+00-2.5+00-2.7+00-2.9+00-3.1+00-3.2+00-3.2+00-3.2+00-3.1+00-2.9+00-2.7+00-2.5+00-2.3+00-2.1+00-2.0+00
-1.9+00-2.1+00-2.3+00-2.5+00-2.6+00-2.8+00-3.0+00-3.1+00-3.1+00-3.1+00-3.0+00-2.8+00-2.6+00-2.5+00-2.3+00-2.1+00-1.9+00
-1.9+00-2.0+00-2.2+00-2.4+00-2.5+00-2.7+00-2.8+00-2.9+00-2.9+00-2.9+00-2.8+00-2.7+00-2.5+00-2.4+00-2.2+00-2.0+00-1.9+00
-1.8+00-2.0+00-2.1+00-2.3+00-2.4+00-2.5+00-2.6+00-2.7+00-2.7+00-2.7+00-2.6+00-2.5+00-2.4+00-2.3+00-2.1+00-2.0+00-1.8+00
-1.8+00-1.9+00-2.0+00-2.1+00-2.3+00-2.4+00-2.5+00-2.5+00-2.5+00-2.5+00-2.5+00-2.4+00-2.3+00-2.1+00-2.0+00-1.9+00-1.8+00
-1.7+00-1.8+00 1.9+00-2.0+00-2.1+00-2.2+00-2.3+00-2.3+00-2.3+00-2.3+00-2.3+00-2.2+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00
-1.6+00-1.7+00-1.8+00-1.9+00-2.0+00-2.0+00-2.1+00-2.1+00-2.1+00-2.1+00-2.1+00-2.0+00-2.0+00-1.9+00-1.8+00-1.7+00-1.6+00
-1.5+00-1.6+00-1.7+00-1.8+00-1.8+00-1.9+00-1.9+00-2.0+00-2.0+00-2.0+00-1.9+00-1.9+00-1.8+00-1.8+00-1.7+00-1.6+00-1.5+00

P(I,J, 4, 2)

-1.6+00-1.7+00-1.8+00-1.8+00-1.9+00-2.0+00-2.0+00-2.1+00-2.1+00-2.1+00-2.0+00-2.0+00-1.9+00-1.8+00-1.8+00-1.7+00-1.6+00
-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.2+00-2.2+00-2.3+00-2.3+00-2.3+00-2.2+00-2.2+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00
-1.8+00-1.9+00-2.0+00-2.1+00-2.2+00-2.3+00-2.4+00-2.5+00-2.5+00-2.5+00-2.4+00-2.3+00-2.2+00-2.1+00-2.0+00-1.9+00-1.8+00
-1.8+00-2.0+00-2.1+00-2.3+00-2.4+00-2.6+00-2.7+00-2.7+00-2 8+00-2.7+00-2.7+00-2.6+00-2.4+00-2.3+00-2.1+00-2.0+00-1.8+00
-1.9+00-2.1+00-2.2+00-2.4+00-2.6+00-2.8+00-2.9+00-3.0+00-3.1+00-3.0+00-2.9+00-2.8+00-2.6+00-2.4+00-2.2+00-2.1+00-1.9+00
-2.0+00-2.2+00-2.3+00-2.6+00-2.8+00-3.0+00-3.2+00-3.3+00-3.4+00 3.3+00-3.2+00-3.0+00-2.8+00-2.6+00-2.3+00-2.2+00-2.0+00
-2.0+00-2.2+00-2.4+00-2.7+00-2.9+00-3.2+00-3.4+00-3.6+00-3.7+00-3.6+00-3.4+00-3.2+00-2.9+00-2.7+00-2.4+00-2.2+00-2.0+00
-2.1+00-2.3+00-2.5+00-2.7+00-3.0+00-3.3+00-3.6+00-3.8+00-3.9+00-3.8+00-3.6+00-3.3+00-3.0+00-2.7+00-2.5+00-2.3+00-2.1+00
-2.1+00-2.3+00-2.5+00-2.8+00-3.1+00 3.4+00-3.7+00-3.9+00-4.0+00-3.9+00-3.7+00-3.4+00-3.1+00-2.8+00-2.5+00-2.3+00-2.1+00
-2.1+00-2.3+00-2.5+00-2.7+00-3.0+00-3.3+00-3.6+00-3.8+00-3.9+00-3.8+00-3.6+00-3.3+00-3.0+00-2.7+00-2.5+00-2.3+00-2.1+00
-2.0+00-2.2+00-2.4+00-2.7+00-2.9+00-3.2+00-3.4+00-3.6+00-3.7+00-3.6+00-3.4+00-3.2+00-2.9+00-2.7+00-2.4+00-2.2+00-2.0+00
-2.0+00-2.2+00-2.3+00-2.6+00-2.8+00-3.0+00-3.2+00-3.3+00-3.4+00-3.3+00-3.2+00-3.0+00-2.8+00-2.6+00-2.3+00-2.2+00-2.0+00
-1.9+00-2.1+00-2.2+00-2.4+00-2.6+00-2.8+00-2.9+00-3.0+00-3.1+00-3.0+00-2.9+00-2.8+00-2.6+00-2.4+00-2.2+00-2.1+00-1.9+00
-1.8+00-2.0+00-2.1+00-2.3+00-2.4+00-2.6+00-2.7+00-2.7+00-2.8+00-2.7+00-2.7+00-2.6+00-2.4+00-2.3+00-2.1+00-2.0+00-1.8 00
-1.8+00-1.9+00-2.0+00-2.1+00-2.2+00-2.3+00-2.4+00-2.5+00-2.5+00-2.5+00-2.4+00-2.3+00-2.2+00-2.1+00-2.0+00-1.9+00-1.8+00
-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.2+00-2.2+00-2.3+00-2.3+00-2.3+00-2.2+00-2.2+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00
-1.6+00-1.7+00-1.8+00-1.8+00-1.9+00-2.0+00-2.0+00-2.1+00-2.1+00-2.1+00-2.0+00-2.0+00-1.9+00-1.8+00-1.8+00-1.7+00-1.6+00
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7-2

P(I,J, 5, 2)

-1.6+00	-1.7+00	-1.8+00	-1.9+00	-2.0+00	-2.1+00	-2.1+00	-2.2+00	-2.2+00	-2.2+00	-2.1+00	-2.1+00	-2.0+00	-1.9+00	-1.8+00	-1.7+00	-1.6+00	
-1.7+00	-1.8+00	-2.0+00	-2.1+00	-2.2+00	-2.3+00	-2.4+00	-2.4+00	-2.4+00	-2.4+00	-2.4+00	-2.3+00	-2.2+00	-2.1+00	-2.0+00	-1.8+00	-1.7+00	
-1.8+00	-2.0+00	-2.1+00	-2.2+00	-2.4+00	-2.5+00	-2.6+00	-2.7+00	-2.7+00	-2.7+00	-2.6+00	-2.5+00	-2.4+00	-2.2+00	-2.1+00	-2.0+00	-1.8+00	
-1.9+00	-2.1+00	-2.2+00	-2.4+00	-2.6+00	-2.8+00	-3.0+00	-3.1+00	-3.1+00	-3.1+00	-3.0+00	-2.8+00	-2.6+00	-2.4+00	-2.2+00	-2.1+00	-1.9+00	
-2.0+00	-2.2+00	-2.4+00	-2.6+00	-2.8+00	-3.1+00	-3.3+00	-3.4+00	-3.5+00	-3.4+00	-3.3+00	-3.1+00	-2.8+00	-2.6+00	-2.4+00	-2.2+00	-2.0+00	
-2.1+00	-2.3+00	-2.5+00	-2.8+00	-3.1+00	-3.4+00	-3.6+00	-3.7+00	-3.7+00	-3.7+00	-3.6+00	-3.4+00	-3.1+00	-2.8+00	-2.5+00	-2.3+00	-2.1+00	
-2.1+00	-2.4+00	-2.6+00	-3.0+00	-3.3+00	-3.6+00	-4.0+00	-4.3+00	-4.4+00	-4.3+00	-4.0+00	-3.6+00	-3.3+00	-3.0+00	-2.6+00	-2.4+00	-2.1+00	
-2.2+00	-2.4+00	-2.7+00	-3.1+00	-3.4+00	-3.9+00	-4.3+00	-4.6+00	-4.6+00	-4.6+00	-4.3+00	-3.9+00	-3.4+00	-3.1+00	-2.7+00	-2.4+00	-2.2+00	
2.2+00	-2.4+00	-2.7+00	-3.1+00	-3.5+00	-3.9+00	-4.4+00	-4.8+00	-4.9+00	-4.8+00	-4.4+00	-3.9+00	-3.5+00	-3.1+00	-2.7+00	-2.4+00	-2.2+00	
-2.2+00	-2.4+00	-2.7+00	-3.1+00	-3.4+00	-3.9+00	-4.3+00	-4.6+00	-4.8+00	-4.6+00	-4.3+00	-3.9+00	-3.4+00	-3.1+00	-2.7+00	-2.4+00	-2.2+00	
-2.1+00	-2.4+00	-2.6+00	-3.0+00	-3.3+00	-3.6+00	-4.0+00	-4.3+00	-4.4+00	-4.3+00	-4.0+00	-3.6+00	-3.3+00	-3.0+00	-2.6+00	-2.4+00	-2.1+00	
-2.1+00	-2.3+00	-2.5+00	-2.8+00	-3.1+00	-3.4+00	-3.6+00	-3.9+00	-3.9+00	-3.9+00	-3.6+00	-3.4+00	-3.1+00	-2.8+00	-2.5+00	-2.3+00	-2.1+00	
-2.0+00	-2.2+00	-2.4+00	-2.6+00	-2.8+00	-3.1+00	-3.3+00	-3.4+00	-3.5+00	-3.4+00	-3.3+00	-3.1+00	-2.8+00	-2.6+00	-2.4+00	-2.2+00	-2.0+00	
-1.9+00	-2.1+00	-2.2+00	-2.4+00	-2.6+00	-2.8+00	-3.0+00	-3.1+00	-3.1+00	-3.1+00	-3.0+00	-2.8+00	-2.6+00	-2.4+00	-2.2+00	-2.1+00	-1.9+00	
-1.8+00	-2.0+00	-2.1+00	-2.2+00	-2.4+00	-2.5+00	-2.6+00	-2.7+00	-2.7+00	-2.7+00	-2.6+00	-2.5+00	-2.4+00	-2.2+00	-2.1+00	-2.0+00	-1.8+00	
-1.7+00	-1.8+00	-2.0+00	-2.1+00	-2.2+00	-2.3+00	-2.4+00	-2.4+00	-2.4+00	-2.4+00	-2.4+00	-2.3+00	-2.2+00	-2.1+00	-2.0+00	-1.8+00	-1.7+00	
-1.6+00	-1.7+00	-1.8+00	-1.9+00	-2.0+00	-2.1+00	-2.1+00	-2.2+00	-2.2+00	-2.2+00	-2.1+00	-2.1+00	-2.0+00	-1.9+00	-1.8+00	-1.7+00	-1.6+00	

P(I,J, 6, 2)

-1.7+00	-1.8+00	-1.9+00	-2.0+00	-2.1+00	-2.2+00	-2.2+00	-2.3+00	-2.3+00	-2.3+00	-2.2+00	-2.2+00	-2.1+00	-2.0+00	-1.9+00	-1.8+00	-1.7+00	
-1.8+00	-1.9+00	-2.0+00	-2.2+00	-2.3+00	-2.4+00	-2.5+00	-2.6+00	-2.6+00	-2.6+00	-2.5+00	-2.4+00	-2.3+00	-2.2+00	-2.0+00	-1.9+00	-1.8+00	
-1.9+00	-2.0+00	-2.2+00	-2.4+00	-2.5+00	-2.7+00	-2.8+00	-2.9+00	-2.9+00	-2.9+00	-2.8+00	-2.7+00	-2.5+00	-2.4+00	-2.2+00	-2.0+00	-1.9+00	
-2.0+00	-2.2+00	-2.4+00	-2.6+00	-2.8+00	-3.0+00	-3.2+00	-3.3+00	-3.4+00	-3.3+00	-3.2+00	-3.0+00	-2.8+00	-2.6+00	-2.4+00	-2.2+00	-2.0+00	
-2.1+00	-2.3+00	-2.5+00	-2.8+00	-3.1+00	-3.4+00	-3.6+00	-3.9+00	-3.9+00	-3.9+00	-3.6+00	-3.4+00	-3.1+00	-2.8+00	-2.5+00	-2.3+00	-2.1+00	
-2.2+00	-2.4+00	-2.7+00	-3.0+00	-3.4+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-3.4+00	-3.0+00	-2.7+00	-2.4+00	-2.2+00	
-2.2+00	-2.5+00	-2.8+00	-3.2+00	-3.6+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-3.6+00	-3.2+00	-2.8+00	-2.5+00	-2.2+00	
-2.3+00	-2.6+00	-2.9+00	-3.3+00	-3.9+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-3.9+00	-3.3+00	-2.9+00	-2.6+00	-2.3+00	
-2.3+00	-2.6+00	-2.9+00	-3.4+00	-3.9+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-3.9+00	-3.4+00	-2.9+00	-2.6+00	-2.3+00	
-2.3+00	-2.6+00	-2.9+00	-3.3+00	-3.9+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-3.9+00	-3.3+00	-2.9+00	-2.6+00	-2.3+00	
-2.2+00	-2.5+00	-2.8+00	-3.2+00	-3.6+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-3.6+00	-3.2+00	-2.8+00	-2.5+00	-2.2+00	
-2.2+00	-2.4+00	-2.7+00	-3.0+00	-3.4+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-3.4+00	-3.0+00	-2.7+00	-2.4+00	-2.2+00	
-2.1+00	-2.3+00	-2.5+00	-2.8+00	-3.1+00	-3.4+00	-3.6+00	-3.9+00	-3.9+00	-3.9+00	-3.6+00	-3.4+00	-3.1+00	-2.8+00	-2.5+00	-2.3+00	-2.1+00	
-2.0+00	-2.2+00	-2.4+00	-2.6+00	-2.8+00	-3.0+00	-3.2+00	-3.3+00	-3.4+00	-3.3+00	-3.2+00	-3.0+00	-2.8+00	-2.6+00	-2.4+00	-2.2+00	-2.0+00	
-1.9+00	-2.0+00	-2.2+00	-2.4+00	-2.5+00	-2.7+00	-2.8+00	-2.9+00	-2.9+00	-2.9+00	-2.8+00	-2.7+00	-2.5+00	-2.4+00	-2.2+00	-2.0+00	-1.9+00	
-1.8+00	-1.9+00	-2.0+00	-2.2+00	-2.3+00	-2.4+00	-2.5+00	-2.6+00	-2.6+00	-2.6+00	-2.5+00	-2.4+00	-2.3+00	-2.2+00	-2.0+00	-1.9+00	-1.8+00	
-1.7+00	-1.8+00	-1.9+00	-2.0+00	-2.1+00	-2.2+00	-2.2+00	-2.3+00	-2.3+00	-2.3+00	-2.2+00	-2.2+00	-2.1+00	-2.0+00	-1.9+00	-1.8+00	-1.7+00	

P(I,J, 7, 2)

-1.7+00	-1.8+00	-1.9+00	-2.0+00	-2.1+00	-2.2+00	-2.3+00	-2.4+00	-2.4+00	-2.4+00	-2.3+00	-2.2+00	-2.1+00	-2.0+00	-1.9+00	-1.8+00	-1.7+00	
-1.8+00	-1.9+00	-2.1+00	-2.2+00	-2.4+00	-2.5+00	-2.6+00	-2.7+00	-2.7+00	-2.7+00	-2.6+00	-2.5+00	-2.4+00	-2.2+00	-2.1+00	-1.9+00	-1.8+00	
-1.9+00	-2.1+00	-2.3+00	-2.4+00	-2.6+00	-2.8+00	-3.0+00	-3.1+00	-3.1+00	-3.1+00	-3.0+00	-2.8+00	-2.6+00	-2.4+00	-2.3+00	-2.1+00	-1.9+00	
-2.0+00	-2.2+00	-2.4+00	-2.7+00	-2.9+00	-3.2+00	-3.4+00	-3.6+00	-3.7+00	-3.6+00	-3.4+00	-3.2+00	-2.9+00	-2.7+00	-2.4+00	-2.2+00	-2.0+00	
-2.1+00	-2.4+00	-2.6+00	-2.9+00	-3.3+00	-3.6+00	-4.0+00	-4.3+00	-4.4+00	-4.3+00	-4.0+00	-3.6+00	-3.3+00	-2.9+00	-2.6+00	-2.4+00	-2.1+00	
-2.2+00	-2.5+00	-2.8+00	-3.2+00	-3.6+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-3.6+00	-3.2+00	-2.8+00	-2.5+00	-2.2+00	
-2.3+00	-2.6+00	-3.0+00	-3.4+00	-4.0+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-4.0+00	-3.4+00	-3.0+00	-2.6+00	-2.3+00	
-2.4+00	-2.7+00	-3.1+00	-3.6+00	-4.3+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-4.3+00	-3.6+00	-3.1+00	-2.7+00	-2.4+00	
-2.4+00	-2.7+00	-3.1+00	-3.7+00	-4.4+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-4.4+00	-3.7+00	-3.1+00	-2.7+00	-2.4+00	
-2.4+00	-2.7+00	-3.1+00	-3.6+00	-4.3+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-4.3+00	-3.6+00	-3.1+00	-2.7+00	-2.4+00	
-2.3+00	-2.6+00	-3.0+00	-3.4+00	-4.0+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-4.0+00	-3.4+00	-3.0+00	-2.6+00	-2.3+00	
-2.2+00	-2.5+00	-2.8+00	-3.2+00	-3.6+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-3.6+00	-3.2+00	-2.8+00	-2.5+00	-2.2+00	

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-2.1+00-2.4+00-2.6+00-2.9+00-3.3+00-3.6+00-4.0+00-4.3+00-4.4+00-4.3+00-4.0+00-3.6+00-3.3+00-2.9+00-2.6+00-2.4+00-2.1+00
-2.0+00-2.2+00-2.4+00-2.7+00-2.9+00-3.2+00-3.4+00-3.6+00-3.7+00-3.6+00-3.4+00-3.2+00-2.9+00-2.7+00-2.4+00-2.2+00-2.0+00
-1.9+00-2.1+00-2.3+00-2.4+00-2.6+00-2.8+00-3.0+00-3.1+00-3.1+00-3.1+00-3.0+00-2.8+00-2.6+00-2.4+00-2.3+00-2.1+00-1.9+00
-1.8+00-1.9+00-2.1+00-2.2+00-2.4+00-2.5+00-2.6+00-2.7+00-2.7+00-2.7+00-2.6+00-2.5+00-2.4+00-2.2+00-2.1+00-1.9+00-1.8+00
-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.2+00-2.3+00-2.4+00-2.4+00-2.4+00-2.4+00-2.3+00-2.2+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00
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P(I,J, 8, 2)

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-1.7+00-1.8+00-2.0+00-2.1+00-2.2+00-2.3+00-2.4+00-2.4+00-2.4+00-2.4+00-2.4+00-2.3+00-2.2+00-2.1+00-2.0+00-1.8+00-1.7+00
-1.8+00-2.0+00-2.1+00-2.3+00-2.4+00-2.6+00-2.7+00-2.8+00-2.8+00-2.8+00-2.7+00-2.6+00-2.4+00-2.3+00-2.1+00-2.0+00-1.8+00
-2.0+00-2.1+00-2.3+00-2.5+00-2.7+00-2.9+00-3.1+00-3.2+00-3.2+00-3.2+00-3.1+00-2.9+00-2.7+00-2.5+00-2.3+00-2.1+00-2.0+00
-2.1+00-2.3+00-2.5+00-2.7+00-3.0+00-3.3+00-3.6+00-3.8+00-3.8+00-3.8+00-3.6+00-3.3+00-3.0+00-2.7+00-2.5+00-2.3+00-2.1+00
-2.2+00-2.4+00-2.7+00-3.0+00-3.4+00-3.9+00-4.3+00-4.6+00-4.8+00-4.6+00-4.3+00-3.9+00-3.4+00-3.0+00-2.7+00-2.4+00-2.2+00
-2.3+00-2.6+00-2.9+00-3.3+00-3.9+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -3.9+00-3.3+00-2.9+00-2.6+00-2.3+00
-2.4+00-2.7+00-3.1+00-3.6+00-4.3+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -4.3+00-3.6+00-3.1+00-2.7+00-2.4+00
-2.4+00-2.8+00-3.2+00-3.8+00-4.6+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -4.6+00-3.8+00-3.2+00-2.8+00-2.4+00
-2.4+00-2.8+00-3.2+00-3.8+00-4.8+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -4.8+00-3.9+00-3.2+00-2.8+00-2.4+00
-2.4+00-2.8+00-3.2+00-3.8+00-4.6+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -4.6+00-3.8+00-3.2+00-2.8+00-2.4+00
-2.4+00-2.7+00-3.1+00-3.6+00-4.3+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -4.3+00-3.6+00-3.1+00-2.7+00-2.4+00
-2.3+00-2.6+00-2.9+00-3.3+00-3.9+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -3.9+00-3.3+00-2.9+00-2.6+00-2.3+00
-2.2+00-2.4+00-2.7+00-3.0+00-3.4+00-3.9+00-4.3+00-4.6+00-4.8+00-4.6+00-4.3+00-3.9+00-3.4+00-3.0+00-2.7+00-2.4+00-2.2+00
-2.1+00-2.3+00-2.5+00-2.7+00-3.0+00-3.3+00-3.6+00-3.8+00-3.9+00-3.8+00-3.6+00-3.3+00-3.0+00-2.7+00-2.5+00-2.3+00-2.1+00
-2.0+00-2.1+00-2.3+00-2.5+00-2.7+00-2.9+00-3.1+00-3.2+00-3.2+00-3.2+00-3.1+00-2.9+00-2.7+00-2.5+00-2.3+00-2.1+00-2.0+00
-1.8+00-2.0+00-2.1+00-2.3+00-2.4+00-2.6+00-2.7+00-2.8+00-2.8+00-2.8+00-2.7+00-2.6+00-2.4+00-2.3+00-2.1+00-2.0+00-1.8+00
-1.7+00-1.8+00-2.0+00-2.1+00-2.2+00-2.3+00-2.4+00-2.4+00-2.4+00-2.4+00-2.4+00-2.3+00-2.2+00-2.1+00-2.0+00-1.8+00-1.7+00
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P(I,J, 9, 2)

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-1.7+00-1.8+00-2.0+00-2.1+00-2.2+00-2.3+00-2.4+00-2.4+00-2.5+00-2.4+00-2.4+00-2.3+00-2.2+00-2.1+00-2.0+00-1.8+00-1.7+00
-1.8+00-2.0+00-2.1+00-2.3+00-2.4+00-2.6+00-2.7+00-2.8+00-2.8+00-2.7+00-2.6+00-2.4+00-2.3+00-2.1+00-2.0+00-1.8+00
-2.0+00-2.1+00-2.3+00-2.5+00-2.7+00-2.9+00-3.1+00-3.2+00-3.3+00-3.2+00-3.1+00-2.9+00-2.7+00-2.5+00-2.3+00-2.1+00-2.0+00
-2.1+00-2.3+00-2.5+00-2.8+00-3.1+00-3.4+00-3.6+00-3.8+00-3.9+00-3.8+00-3.6+00-3.4+00-3.1+00-2.8+00-2.5+00-2.3+00-2.1+00
-2.2+00-2.4+00-2.7+00-3.1+00-3.5+00-3.9+00-4.4+[illegible]8+00-4.9+00-4.8+00-4.4+00-3.9+00-3.5+00-3.1+00-2.7+00-2.4+00-2.2+00
-2.3+00-2.6+00-2.9+00-3.4+00-3.9+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -3.9+00-[illegible]+00-2.9+00-2.6+00-2.3+00
-2.4+00-2.7+00-3.1+00-3.6+00-4.4+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -4.4+00-3.[illegible]+00-3.1+00-2.7+00-2.4+00
-2.4+00-2.8+00-3.2+00-3.8+00-4.8+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -4.8+00-3.9+00-3.2+00-2.8+00-2.4+00
-2.5+00-2.8+00-3.3+00-3.9+00-4.9+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -4.9+00-4.0+00-3.3+00-2.8+00-2.5+00
-2.4+00-2.8+00-3.2+00-3.8+00-4.8+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -4.8+00-3.9+00-3.2+00-2.8+00-2.4+00
-2.4+00-2.7+00-3.1+00-3.6+00-4.4+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -4.4+00-3.7+00-3.1+00-2.7+00-2.4+00
-2.3+00-2.6+00-2.9+00-3.4+00-3.9+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -3.9+00-3.4+00-2.9+00-2.6+00-2.3+00
-2.2+00-2.4+00-2.7+00-3.1+00-3.5+00-3.9+00-4.4+00-4.8+00-4.9+00-4.8+00-4.4+00-3.9+00-3.5+00-3.1+00-2.7+00-2.4+00-2.2+00
-2.1+00-2.3+00-2.5+00-2.8+00-3.1+00-3.4+00-3.7+00-3.9+00-4.0+00-3.9+00-3.7+00-3.4+00-3.1+00-2.8+00-2.5+00-2.3+00-2.1+00
-2.0+00-2.1+00-2.3+00-2.5+00-2.7+00-2.9+00-3.1+00-3.2+00-3.3+00-3.2+00-3.1+00-2.9+00-2.7+00-2.5+00-2.3+00-2.1+00-2.0+00
-1.8+00-2.0+00-2.1+00-2.3+00-2.4+00-2.6+00-2.7+00-2.8+00-2.8+00-2.8+00-2.7+00-2.6+00-2.4+00-2.3+00-2.1+00-2.0+00-1.8+00
-1.7+00-1.8+00-2.0+00-2.1+00-2.2+00-2.3+00-2.4+00-2.4+00-2.5+00-2.4+00-2.4+00-2.3+00-2.2+00-2.1+00-2.0+00-1.8+00-1.7+00
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P(I,J,10, 2)

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-1.7+00-1.8+00-2.0+00-2.1+00-2.2+00-2.3+00-2.4+00-2.4+00-2.4+00-2.4+00-2.4+00-2.3+00-2.2+00-2.1+00-2.0+00-1.8+00-1.7+00
-1.8+00-2.0+00-2.1+00-2.3+00-2.4+00-2.6+00-2.7+00-2.8+00-2.8+00-2.8+00-2.7+00-2.6+00-2.4+00-2.3+00-2.1+00-2.0+00-1.8+00
-2.0+00-2.1+00-2.3+00-2.5+00-2.7+00-2.9+00-3.1+00-3.2+00-3.2+00-3.2+00-3.1+00-2.9+00-2.7+00-2.5+00-2.3+00-2.1+00-2.0+00
-2.1+00-2.3+00-2.5+00-2.7+00-3.0+00-3.3+00-3.6+00-3.8+00-3.8+00-3.8+00-3.6+00-3.3+00-3.0+00-2.7+00-2.5+00-2.3+00-2.1+00
-2.2+00-2.4+00-2.7+00-3.0+00-3.4+00-3.9+00-4.3+00-4.6+00-4.8+00-4.6+00-4.3+00-3.9+00-3.4+00-3.0+00-2.7+00-2.4+00-2.2+00
-2.3+00-2.6+00-2.9+00-3.3+00-3.9+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -3.9+00-3.3+00-2.9+00-2.6+00-2.3+00
```

```
-2.4+00-2.7+00-3.1+00-3.6+00-4.3+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -4.3+00-3.6+00-3.1+00-2.7+00-2.4+00
-2.4+00-2.8+00-3.2+00-3.8+00-4.6+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -4.6+00-3.8+00-3.2+00-2.8+00-2.4+00
-2.4+00-2.8+00-3.2+00-3.8+00-4.8+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -4.8+00-3.8+00-3.2+00-2.8+00-2.4+00
-2.4+00-2.8+00-3.2+00-3.8+00-4.6+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -4.6+00-3.8+00-3.2+00-2.8+00-2.4+00
-2.4+00-2.7+00-3.1+00-3.6+00-4.3+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -4.3+00-3.6+00-3.1+00-2.7+00-2.4+00
-2.3+00-2.6+00-2.9+00-3.3+00-3.9+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -3.9+00-3.3+00-2.9+00-2.6+00-2.3+00
-2.2+00-2.4+00-2.7+00-3.0+00-3.4+00-3.9+00-4.3+00-4.6+00-4.8+00-4.6+00-4.3+00-3.9+00-3.4+00-3.0+00-2.7+00-2.4+00-2.2+00
-2.1+00-2.3+00-2.5+00-2.7+00-3.0+00-3.3+00-3.6+00-3.8+00-3.9+00-3.8+00-3.6+00-3.3+00-3.0+00-2.7+00-2.5+00-2.3+00-2.1+00
 2.0+00-2.1+00-2.3+00-2.5+00-2.7+00-2.9+00-3.1+00-3.2+00-3.2+00-3.2+00-3.1+00-2.9+00-2.7+00-2.5+00-2.3+00-2.1+00-2.0+00
-1.8+00-2.0+00-2.1+00-2.3+00-2.4+00-2.6+00-2.7+00-2.8+00-2.8+00-2.8+00-2.7+00-2.6+00-2.4+00-2.3+00-2.1+00-2.0+00-1.8+00
- .7+00-1.8+00-2.0+00-2.1+00-2.2+00-2.3+00-2.4+00-2.4+00-2.4+00-2.4+00-2.4+00-2.3+00-2.2+00-2.1+00-2.0+00-1.8+00-1.7+00
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P(I,J,11, 2)

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-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.2+00-2.3+00-2.4+00-2.4+00-2.4+00-2.3+00-2.2+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00
-1.8+00-1.9+00-2.1+00-2.2+00-2.4+00-2.5+00-2.6+00-2.7+00-2.7+00-2.7+00-2.6+00-2.5+00-2.4+00-2.2+00-2.1+00-1.9+00-1.8+00
-1.9+00-2.1+00-2.3+00-2.4+00-2.6+00-2.8+00-3.0+00-3.1+00-3.1+00-3.1+00-3.0+00-2.8+00-2.6+00-2.4+00-2.3+00-2.1+00-1.9+00
-2.0+00-2.2+00-2.4+00-2.7+00-2.9+00-3.2+00-3.4+00-3.6+00-3.7+00-3.6+00-3.4+00-3.2+00-2.9+00-2.7+00-2.4+00-2.2+00-2.0+00
-2.1+00-2.4+00-2.6+00-2.9+00-3.3+00-3.6+00-4.0+00-4.3+00-4.4+00-4.3+00-4.0+00-3.6+00-3.3+00-2.9+00-2.6+00-2.4+00-2.1+00
-2.2+00-2.5+00-2.8+00-3.2+00-3.6+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -3.6+00-3.2+00-2.8+00-2.5+00-2.2+00
-2.3+00-2.6+00-3.0+00-3.4+00-4.0+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -4.0+00-3.4+00-3.0+00-2.6+00-2.3+00
-2.4+00-2.7+00-3.1+00-3.6+00-4.3+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -4.3+00-3.6+00-3.1+00-2.7+00-2.4+00
-2.4+00-2.7+00-3.1+00-3.7+00-4.4+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -4.4+00-3.7+00-3.1+00-2.7+00-2.4+00
-2.4+00-2.7+00-3.1+00-3.6+00-4.3+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -4.3+00-3.6+00-3.1+00-2.7+00-2.4+00
-2.3+00-2.6+00-3.0+00-3.4+00-4.0+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -4.0+00-3.5+00-3.0+00-2.6+00-2.3+00
-2.2+00-2.5+00-2.8+00-3.2+00-3.6+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -3.6+00-3.2+00-2.8+00-2.5+00-2.2+00
-2.1+00-2.4+00-2.6+00-2.9+00-3.3+00-3.6+00-4.0+00-4.3+00-4.4+00-4.3+00-4.0+00-3.6+00-3.3+00-2.9+00-2.6+00-2.4+00-2.1+00
-2.0+00-2.2+00-2.4+00-2.7+00-2.9+00-3.2+00-3.4+00-3.6+00-3.7+00-3.6+00-3.5+00-3.2+00-2.9+00-2.7+00-2.4+00-2.2+00-2.0+00
-1.9+00-2.1+00-2.3+00-2.4+00-2.6+00-2.8+00-3.0+00-3.1+00-3.1+00-3.1+00-3.0+00-2.8+00-2.6+00-2.4+00-2.3+00-2.1+00-1.9+00
-1.8+00-1.9+00-2.1+00-2.2+00-2.4+00-2.5+00-2.6+00-2.7+00-2.7+00-2.7+00-2.6+00-2.5+00-2.4+00-2.2+00-2.1+00-1.9+00-1.8+00
-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.2+00-2.3+00-2.4+00-2.4+00-2.4+00-2.3+00-2.2+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00
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P(I,J,12, 2)

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-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.2+00-2.2+00-2.3+00-2.3+00-2.3+00-2.2+00-2.2+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00
-1.8+00-1.9+00-2.0+00-2.2+00-2.3+00-2.4+00-2.5+00-2.6+00-2.6+00-2.6+00-2.5+00-2.4+00-2.3+00-2.2+00-2.0+00-1.9+00-1.8+00
-1.9+00-2.0+00-2.2+00-2.4+00-2.5+00-2.7+00-2.8+00-2.9+00-2.9+00-2.9+00-2.8+00-2.7+00-2.5+00-2.4+00-2.2+00-2.0+00-1.9+00
-2.0+00-2.2+00-2.4+00-2.6+00-2.8+00-3.0+00-3.2+00-3.3+00-3.4+00-3.3+00-3.2+00-3.0+00-2.8+00-2.6+00-2.4+00-2.2+00-2.0+00
-2.1+00-2.3+00-2.5+00-2.8+00-3.1+00-3.4+00-3.6+00-3.9+00-3.9+00-3.9+00-3.6+00-3.4+00-3.1+00-2.8+00-2.5+00-2.3+00-2.1+00
-2.2+00-2.4+00-2.7+00-3.0+00-3.4+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -3.4+00-3.0+00-2.7+00-2.4+00-2.2+00
-2.2+00-2.5+00-2.8+00-3.2+00-3.6+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -3.6+00-3.2+00-2.8+00-2.5+00-2.2+00
-2.3+00-2.6+00-2.9+00-3.3+00-3.9+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -3.9+00-3.3+00-2.9+00-2.6+00-2.3+00
-2.3+00-2.6+00-2.9+00-3.4+00-3.9+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -3.9+00-3.4+00-2.9+00-2.6+00-2.3+00
-2.3+00-2.6+00-2.9+00-3.3+00-3.9+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -3.9+00-3.3+00-2.9+00-2.6+00-2.3+00
-2.2+00-2.5+00-2.8+00-3.2+00-3.6+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -3.6+00-3.2+00-2.8+00-2.5+00-2.2+00
-2.2+00-2.4+00-2.7+00-3.0+00-3.4+00 0.0     0.0     0.0     0.0     0.0     0.0     0.0     -3.4+00-3.0+00-2.7+00-2.4+00-2.2+00
-2.1+00-2.3+00-2.5+00-2.8+00-3.1+00-3.4+00-3.6+00-3.9+00-3.9+00-3.9+00-3.6+00-3.4+00-3.1+00-2.8+00-2.5+00-2.3+00-2.1+00
-2.0+00-2.2+00-2.4+00-2.6+00-2.8+00-3.0+00-3.2+00-3.3+00-3.4+00-3.3+00-3.2+00-3.0+00-2.8+00-2.6+00-2.4+00-2.2+00-2.0+00
-1.9+00-2.0+00-2.2+00-2.4+00-2.5+00-2.7+00-2.8+00-2.9+00-2.9+00-2.9+00-2.8+00-2.7+00-2.5+00-2.4+00-2.2+00-2.0+00-1.9+00
-1.8+00-1.9+00-2.0+00-2.2+00-2.3+00-2.4+00-2.5+00-2.6+00-2.6+00-2.6+00-2.5+00-2.4+00-2.3+00-2.2+00-2.0+00-1.9+00-1.8+00
-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.2+00-2.2+00-2.3+00-2.3+00-2.3+00-2.2+00-2.2+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00
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P(I,J,13, 2)

```
-1.6+00-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.1+00-2.2+00-2.2+00-2.2+00-2.1+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00-1.6+00
-1.7+00-1.8+00-2.0+00-2.1+00-2.2+00-2.3+00-2.4+00-2.4+00-2.4+00-2.4+00-2.4+00-2.3+00-2.1+00-2.0+00-1.8+00-1.7+00
-1.8+00-2.0+00-2.1+00-2.2+00-2.4+00-2.5+00-2.6+00-2.7+00-2.7+00-2.7+00-2.6+00-2.5+00-2.4+00-2.2+00-2.1+00-2.0+00-1.8+00
-1.9+00-2.1+00-2.3+00-2.4+00-2.6+00-2.8+00-3.0+00-3.1+00-3.1+00-3.1+00-3.0+00-2.8+00-2.6+00-2.4+00-2.2+00-2.1+00-1.9+00
-2.0+00-2.2+00-2.4+00-2.6+00-2.8+00-3.1+00-3.3+00-3.4+00-3.5+00-3.4+00-3.3+00-3.1+00-2.8+00-2.6+00-2.4+00-2.2+00-2.0+00
-2.1+00-2.3+00-2.5+00-2.8+00-3.1+00-3.4+00-3.6+00-3.9+00-3.9+00-3.9+00-3.6+00-3.4+00-3.1+00-2.8+00-2.5+00-2.3+00-2.1+00
-2.1+00-2.4+00-2.6+00-3.0+00-3.3+00-3.6+00-4.0+00-4.3+00-4.4+00-4.3+00-4.0+00-3.6+00-3.3+00-3.0+00-2.6+00-2.4+00-2.1+00
-2.2+00-2.4+00-2.7+00-3.1+00-3.4+00-3.9+00-4.3+00-4.6+00-4.8+00-4.6+00-4.3+00-3.9+00-3.4+00-3.1+00-2.7+00-2.4+00-2.2+00
-2.2+00-2.4+00-2.7+00-3.1+00-3.5+00-3.9+00-4.4+00-4.8+00-4.9+00-4.8+00-4.4+00-3.9+00-3.5+00-3.1+00-2.7+00-2.4+00-2.2+00
-2.2+00-2.4+00-2.7+00-3.1+00-3.4+00-3.9+00-4.3+00-4.6+00-4.8+00-4.6+00-4.3+00-3.9+00-3.4+00-3.1+00-2.7+00-2.4+00-2.2+00
-2.1+00-2.4+00-2.6+00-3.0+00-3.3+00-3.6+00-4.0+00-4.3+00-4.4+00-4.3+00-4.0+00-3.6+00-3.3+00-3.0+00-2.6+00-2.4+00-2.1+00
-2.1+00-2.3+00-2.5+00-2.8+00-3.1+00-3.4+00-3.6+00-3.9+00-3.9+00-3.9+00-3.6+00-3.4+00-3.1+00-2.8+00-2.5+00-2.3+00-2.1+00
-2.0+00-2.2+00-2.4+00-2.6+00-2.8+00-3.1+00-3.3+00-3.4+00-3.5+00-3.4+00-3.3+00-3.1+00-2.8+00-2.6+00-2.4+00-2.2+00-2.0+00
-1.9+00-2.1+00-2.2+00-2.4+00-2.6+00-2.8+00-3.0+00-3.1+00-3.1+00-3.1+00-3.0+00-2.8+00-2.6+00-2.4+00-2.2+00-2.1+00-1.9+00
-1.8+00-2.0+00-2.1+00-2.2+00-2.4+00-2.5+00-2.6+00-2.7+00-2.7+00-2.7+00-2.6+00-2.5+00-2.4+00-2.2+00-2.1+00-2.0+00-1.8+00
-1.7+00-1.8+00-2.0+00-2.1+00-2.2+00-2.3+00-2.4+00-2.4+00-2.4+00-2.4+00-2.4+00-2.3+00-2.2+00-2.1+00-2.0+00-1.8+00-1.7+00
-1.6+00-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.1+00-2.2+00-2.2+00-2.2+00-2.1+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00-1.6+00
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P(I,J,14, 2)

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-1.6+00-1.7+00-1.8+00-1.8+00-1.9+00-2.0+00-2.0+00-2.1+00-2.1+00-2.1+00-2.0+00-2.0+00-1.9+00-1.8+00-1.8+00-1.7+00-1.6+00
-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.2+00-2.2+00-2.3+00-2.3+00-2.3+00-2.2+00-2.2+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00
-1.8+00-1.9+00-2.0+00-2.1+00-2.2+00-2.3+00-2.4+00-2.5+00-2.5+00-2.5+00-2.4+00-2.3+00-2.2+00-2.1+00-2.0+00-1.9+00-1.8+00
-1.9+00-2.0+00-2.1+00-2.2+00-2.4+00-2.6+00-2.7+00-2.7+00-2.8+00-2.7+00-2.7+00-2.6+00-2.4+00-2.3+00-2.1+00-2.0+00-1.8+00
-2.0+00-2.2+00-2.3+00-2.6+00-2.8+00-3.0+00-3.2+00-3.3+00-3.4+00-3.3+00-3.2+00-3.0+00-2.8+00-2.6+00-2.3+00-2.2+00-2.0+00
-2.0+00-2.2+00-2.4+00-2.7+00-2.9+00-3.2+00-3.5+00-3.6+00-3.7+00-3.6+00-3.5+00-3.2+00-2.9+00-2.7+00-2.4+00-2.2+00-2.0+00
-2.1+00-2.3+00-2.5+00-2.7+00-3.0+00-3.3+00-3.6+00-3.8+00-3.9+00-3.9+00-3.8+00-3.4+00-3.0+00-2.7+00-2.5+00-2.3+00-2.1+00
-2.1+00-2.3+00-2.5+00-2.8+00-3.1+00-3.4+00-3.7+00-3.9+00-4.0+00-3.9+00-3.7+00-3.4+00-3.1+00-2.8+00-2.5+00-2.3+00-2.1+00
-2.1+00-2.3+00-2.5+00-2.7+00-3.0+00-3.3+00-3.6+00-3.9+00-3.9+00-3.9+00-3.7+00-3.4+00-3.0+00-2.7+00-2.5+00-2.3+00-2.1+00
-2.0+00-2.2+00-2.4+00-2.7+00-2.9+00-3.2+00-3.5+00-3.6+00-3.7+00-3.7+00-3.5+00-3.2+00-2.9+00-2.7+00-2.4+00-2.2+00-2.0+00
-2.0+00-2.2+00-2.3+00-2.6+00-2.8+00-3.0+00-3.2+00-3.4+00-3.4+00-3.4+00-3.2+00-3.0+00-2.8+00-2.6+00-2.3+00-2.2+00-2.0+00
-1.9+00-2.1+00-2.2+00-2.4+00-2.6+00-2.8+00-2.9+00-3.0+00-3.1+00-3.0+00-2.9+00-2.8+00-2.6+00-2.4+00-2.2+00-2.1+00-1.9+00
-1.8+00-2.0+00-2.1+00-2.3+00-2.4+00-2.6+00-2.7+00-2.7+00-2.7+00-2.6+00-2.7+00-2.6+00-2.4+00-2.3+00-2.1+00-2.0+00-1.8+00
-1.7+00-1.9+00-2.0+00-2.1+00-2.3+00-2.4+00-2.5+00-2.5+00-2.5+00-2.4+00-2.3+00-2.2+00-2.1+00-2.0+00-1.9+00-1.8+00
-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.2+00-2.2+00-2.3+00-2.3+00-2.3+00-2.2+00-2.2+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00
-1.6+00-1.7+00-1.8+00-1.8+00-1.9+00-2.0+00-2.0+00-2.1+00-2.1+00-2.1+00-2.0+00-2.0+00-1.9+00-1.8+00-1.8+00-1.7+00-1.6+00
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P(I,J,15, 2)

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-1.5+00-1.6+00-1.7+00-1.8+00-1.8+00-1.9+00-1.9+00-2.0+00-2.0+00-2.0+00-1.9+00-1.9+00-1.8+00-1.8+00-1.7+00-1.6+00-1.5+00
-1.6+00-1.7+00-1.8+00-1.9+00-2.0+00-2.0+00-2.1+00-2.1+00-2.1+00-2.1+00-2.1+00-2.0+00-2.0+00-1.9+00-1.8+00-1.7+00-1.6+00
-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.2+00-2.3+00-2.3+00-2.3+00-2.3+00-2.3+00-2.2+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00
-1.8+00-1.9+00-2.0+00-2.1+00-2.3+00-2.4+00-2.5+00-2.5+00-2.5+00-2.5+00-2.5+00-2.4+00-2.3+00-2.1+00-2.0+00-1.9+00-1.8+00
-1.8+00-2.0+00-2.1+00-2.3+00-2.4+00-2.5+00-2.6+00-2.7+00-2.7+00-2.7+00-2.6+00-2.5+00-2.4+00-2.3+00-2.1+00-2.0+00-1.8+00
-1.9+00-2.0+00-2.2+00-2.4+00-2.5+00-2.7+00-2.8+00-2.9+00-2.9+00-2.9+00-2.8+00-2.7+00-2.5+00-2.4+00-2.2+00-2.0+00-1.9+00
-1.9+00-2.1+00-2.3+00-2.5+00-2.6+00-2.8+00-3.0+00-3.1+00-3.1+00-3.1+00-3.0+00-2.8+00-2.6+00-2.5+00-2.3+00-2.1+00-1.9+00
-2.0+00-2.1+00-2.3+00-2.5+00-2.7+00-2.9+00-3.1+00-3.2+00-3.2+00-3.2+00-3.1+00-2.9+00-2.7+00-2.5+00-2.3+00-2.1+00-2.0+00
-2.0+00-2.1+00-2.3+00-2.5+00-2.7+00-2.9+00-3.1+00-3.2+00-3.3+00-3.3+00-3.1+00-3.0+00-2.7+00-2.5+00-2.3+00-2.1+00-2.0+00
-2.0+00-2.1+00-2.3+00-2.5+00-2.7+00-2.9+00-3.1+00-3.2+00-3.3+00-3.2+00-3.1+00-2.9+00-2.7+00-2.5+00-2.3+00-2.1+00-2.0+00
-1.9+00-2.1+00-2.3+00-2.5+00-2.6+00-2.8+00-3.0+00-3.1+00-3.1+00-3.1+00-3.0+00-2.8+00-2.6+00-2.5+00-2.3+00-2.1+00-1.9+00
-1.9+00-2.0+00-2.2+00-2.4+00-2.5+00-2.7+00-2.8+00-2.9+00-3.0+00-2.9+00-2.8+00-2.6+00-2.5+00-2.3+00-2.1+00-2.0+00-1.9+00
-1.8+00-2.0+00-2.1+00-2.3+00-2.5+00-2.6+00-2.7+00-2.7+00-2.7+00-2.7+00-2.7+00-2.6+00-2.5+00-2.3+00-2.1+00-2.0+00-1.8+00
-1.8+00-1.9+00-2.0+00-2.1+00-2.3+00-2.5+00-2.6+00-2.6+00-2.6+00-2.6+00-2.6+00-2.5+00-2.3+00-2.1+00-2.0+00-1.9+00-1.8+00
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-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.2+00-2.3+00-2.3+00-2.3+00-2.3+00-2.3+00-2.2+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00
-1.6+00-1.7+00-1.8+00-1.9+00-2.0+00-2.0+00-2.1+00-2.1+00-2.1+00-2.1+00-2.1+00-2.0+00-2.0+00-1.9+00-1.8+00-1.7+00-1.6+00
-1.5+00-1.6+00-1.7+00-1.8+00-1.8+00-1.9+00-1.9+00-2.0+00-2.0+00-2.0+00-1.9+00-1.9+00-1.8+00-1.8+00-1.7+00-1.6+00-1.5+00

P(I,J,16, 2)

-1.5+00-1.5+00-1.6+00-1.7+00-1.7+00-1.8+00-1.8+00-1.8+00-1.8+00-1.8+00-1.8+00-1.8+00-1.7+00-1.7+00-1.6+00-1.5+00-1.5+00
-1.5+00-1.6+00-1.7+00-1.8+00-1.8+00-1.9+00-1.9+00-2.0+00-2.0+00-2.0+00-1.9+00-1.9+00-1.8+00-1.8+00-1.7+00-1.6+00-1.5+00
-1.6+00-1.7+00-1.8+00-1.9+00-2.0+00-2.0+00-2.1+00-2.1+00-2.1+00-2.1+00-2.1+00-2.0+00-2.0+00-1.9+00-1.8+00-1.7+00-1.6+00
-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.2+00-2.2+00-2.3+00-2.3+00-2.3+00-2.2+00-2.2+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00
-1.7+00-1.8+00-2.0+00-2.1+00-2.2+00-2.3+00-2.4+00-2.4+00-2.4+00-2.4+00-2.4+00-2.3+00-2.2+00-2.1+00-2.0+00-1.8+00-1.7+00
-1.8+00-1.9+00-2.0+00-2.2+00-2.3+00-2.4+00-2.5+00-2.6+00-2.6+00-2.6+00-2.5+00-2.4+00-2.3+00-2.2+00-2.0+00-1.9+00-1.8+00
-1.8+00-1.9+00-2.1+00-2.2+00-2.4+00-2.5+00-2.6+00-2.7+00-2.7+00-2.7+00-2.6+00-2.5+00-2.4+00-2.2+00-2.1+00-1.9+00-1.8+00
-1.8+00-2.0+00-2.1+00-2.3+00-2.4+00-2.6+00-2.7+00-2.8+00-2.8+00-2.8+00-2.7+00-2.6+00-2.4+00-2.3+00-2.1+00-2.0+00-1.8+00
-1.8+00-2.0+00-2.1+00-2.3+00-2.4+00-2.6+00-2.7+00-2.8+00-2.8+00-2.8+00-2.7+00-2.6+00-2.4+00-2.3+00-2.1+00-2.0+00-1.8+00
-1.8+00-2.0+00-2.1+00-2.3+00-2.4+00-2.6+00-2.7+00-2.8+00-2.8+00-2.8+00-2.7+00-2.6+00-2.4+00-2.3+00-2.1+00-2.0+00-1.8+00
-1.8+00-1.9+00-2.1+00-2.2+00-2.4+00-2.5+00-2.6+00-2.7+00-2.7+00-2.7+00-2.6+00-2.5+00-2.4+00-2.2+00-2.1+00-1.9+00-1.8+00
-1.8+00-1.9+00-2.0+00-2.2+00-2.3+00-2.4+00-2.5+00-2.6+00-2.6+00-2.6+00-2.5+00-2.4+00-2.3+00-2.2+00-2.0+00-1.9+00-1.8+00
-1.7+00-1.8+00-2.0+00-2.1+00-2.2+00-2.3+00-2.4+00-2.4+00-2.4+00-2.4+00-2.4+00-2.3+00-2.2+00-2.1+00-2.0+00-1.8+00-1.7+00
-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.2+00-2.2+00-2.3+00-2.3+00-2.3+00-2.2+00-2.2+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00
-1.6+00-1.7+00-1.8+00-1.9+00-2.0+00-2.0+00-2.1+00-2.1+00-2.1+00-2.1+00-2.1+00-2.0+00-2.0+00-1.9+00-1.8+00-1.7+00-1.6+00
-1.5+00-1.6+00-1.7+00-1.8+00-1.8+00-1.9+00-1.9+00-2.0+00-2.0+00-2.0+00-1.9+00-1.9+00-1.8+00-1.8+00-1.7+00-1.6+00-1.5+00
-1.5+00-1.5+00-1.6+00-1.7+00-1.7+00-1.8+00-1.8+00-1.8+00-1.8+00-1.8+00-1.8+00-1.8+00-1.7+00-1.7+00-1.6+00-1.5+00-1.5+00

P(I,J,17, 2)

-1.4+00-1.5+00-1.5+00-1.6+00-1.6+00-1.7+00-1.7+00-1.7+00-1.7+00-1.7+00-1.7+00-1.7+00-1.6+00-1.6+00-1.5+00-1.5+00-1.4+00
-1.5+00-1.5+00-1.6+00-1.7+00-1.7+00-1.8+00-1.8+00-1.8+00-1.8+00-1.8+00-1.8+00-1.8+00-1.7+00-1.7+00-1.6+00-1.5+00-1.5+00
-1.5+00-1.6+00-1.7+00-1.8+00-1.8+00-1.9+00-1.9+00-2.0+00-2.0+00-2.0+00-1.9+00-1.9+00-1.8+00-1.8+00-1.7+00-1.6+00-1.5+00
-1.6+00-1.7+00-1.8+00-1.8+00-1.9+00-2.0+00-2.0+00-2.1+00-2.1+00-2.1+00-2.0+00-2.0+00-1.9+00-1.8+00-1.8+00-1.7+00-1.6+00
-1.6+00-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.1+00-2.2+00-2.2+00-2.2+00-2.1+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00-1.6+00
-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.2+00-2.2+00-2.3+00-2.3+00-2.3+00-2.2+00-2.2+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00
-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.2+00-2.3+00-2.4+00-2.4+00-2.4+00-2.3+00-2.2+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00
-1.7+00-1.8+00-2.0+00-2.1+00-2.2+00-2.3+00-2.4+00-2.4+00-2.4+00-2.4+00-2.4+00-2.3+00-2.2+00-2.1+00-2.0+00-1.8+00-1.7+00
-1.7+00-1.8+00-2.0+00-2.1+00-2.2+00-2.3+00-2.4+00-2.4+00-2.5+00-2.4+00-2.4+00-2.3+00-2.2+00-2.1+00-2.0+00-1.8+00-1.7+00
-1.7+00-1.8+00-2.0+00-2.1+00-2.2+00-2.3+00-2.4+00-2.4+00-2.4+00-2.4+00-2.4+00-2.3+00-2.2+00-2.1+00-2.0+00-1.8+00-1.7+00
-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.2+00-2.3+00-2.4+00-2.4+00-2.4+00-2.3+00-2.2+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00
-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.2+00-2.2+00-2.3+00-2.3+00-2.3+00-2.2+00-2.2+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00
-1.6+00-1.7+00-1.8+00-1.9+00-2.0+00-2.1+00-2.1+00-2.2+00-2.2+00-2.2+00-2.1+00-2.1+00-2.0+00-1.9+00-1.8+00-1.7+00-1.6+00
-1.6+00-1.7+00-1.8+00-1.8+00-1.9+00-2.0+00-2.0+00-2.1+00-2.1+00-2.1+00-2.0+00-2.0+00-1.9+00-1.8+00-1.8+00-1.7+00-1.6+00
-1.5+00-1.6+00-1.7+00-1.8+00-1.8+00-1.9+00-1.9+00-2.0+00-2.0+00-2.0+00-1.9+00-1.9+00-1.8+00-1.8+00-1.7+00-1.6+00-1.5+00
-1.5+00-1.5+00-1.6+00-1.7+00-1.7+00-1.8+00-1.8+00-1.8+00-1.8+00-1.8+00-1.8+00-1.8+00-1.7+00-1.7+00-1.6+00-1.5+00-1.5+00
-1.4+00-1.5+00-1.5+00-1.6+00-1.6+00-1.7+00-1.7+00-1.7+00-1.7+00-1.7+00-1.7+00-1.7+00-1.6+00-1.6+00-1.5+00-1.5+00-1.4+00

IP = 10   IR = 12   IU = 13   ISPARE = 14   IPSAVE = 10

LAST CYCLE COMPLETED IS   2
```

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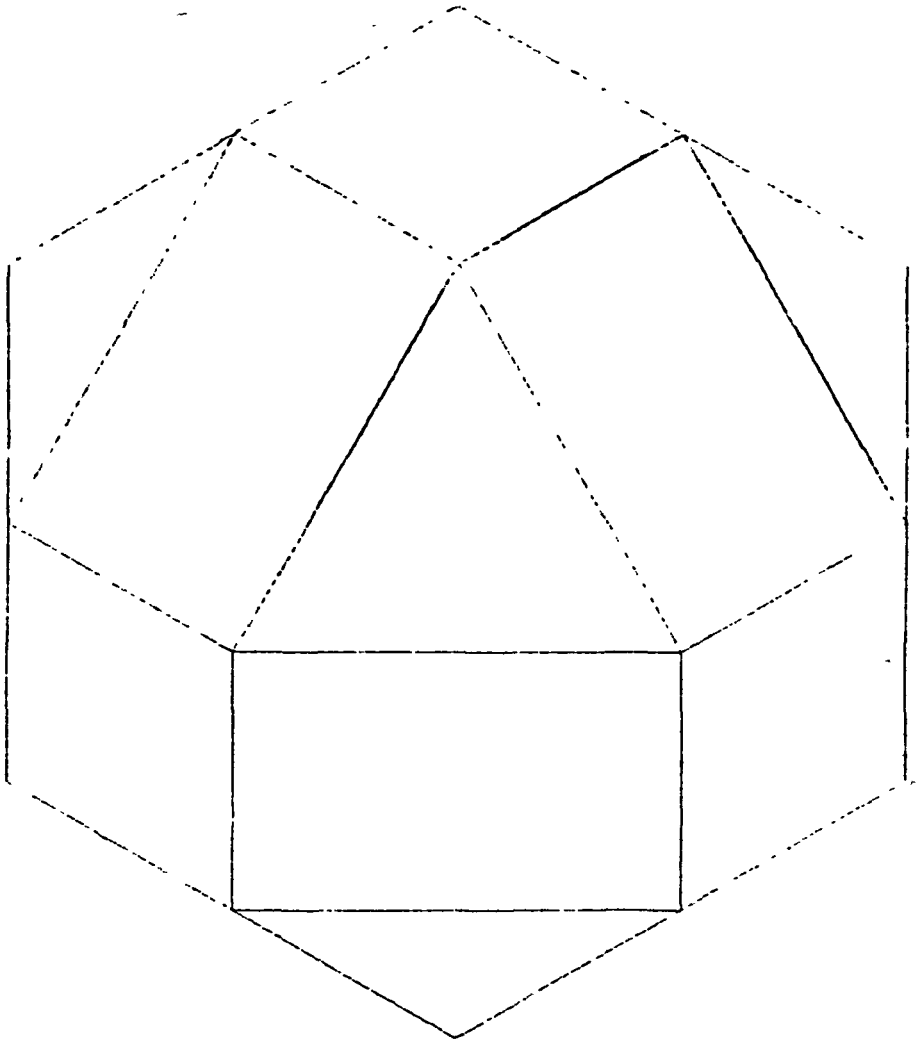
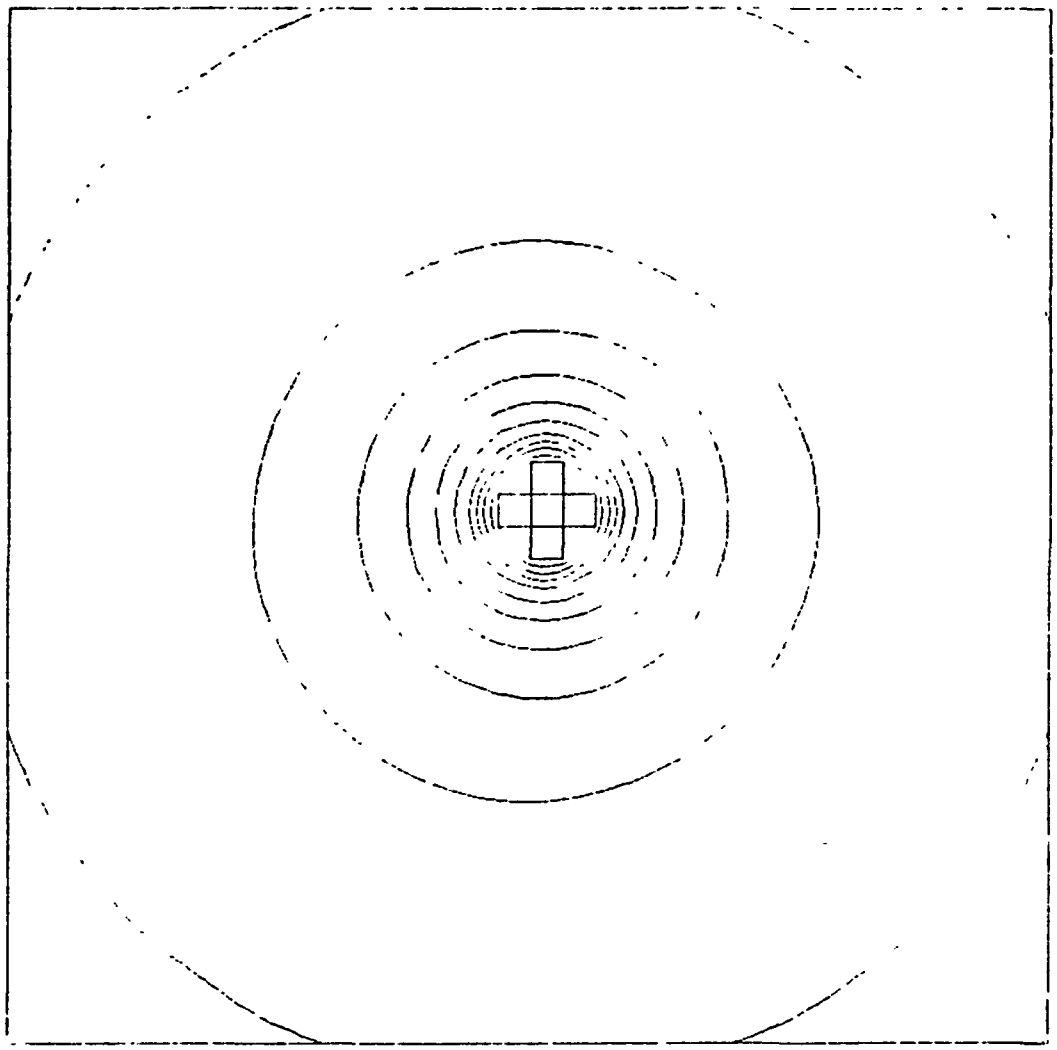
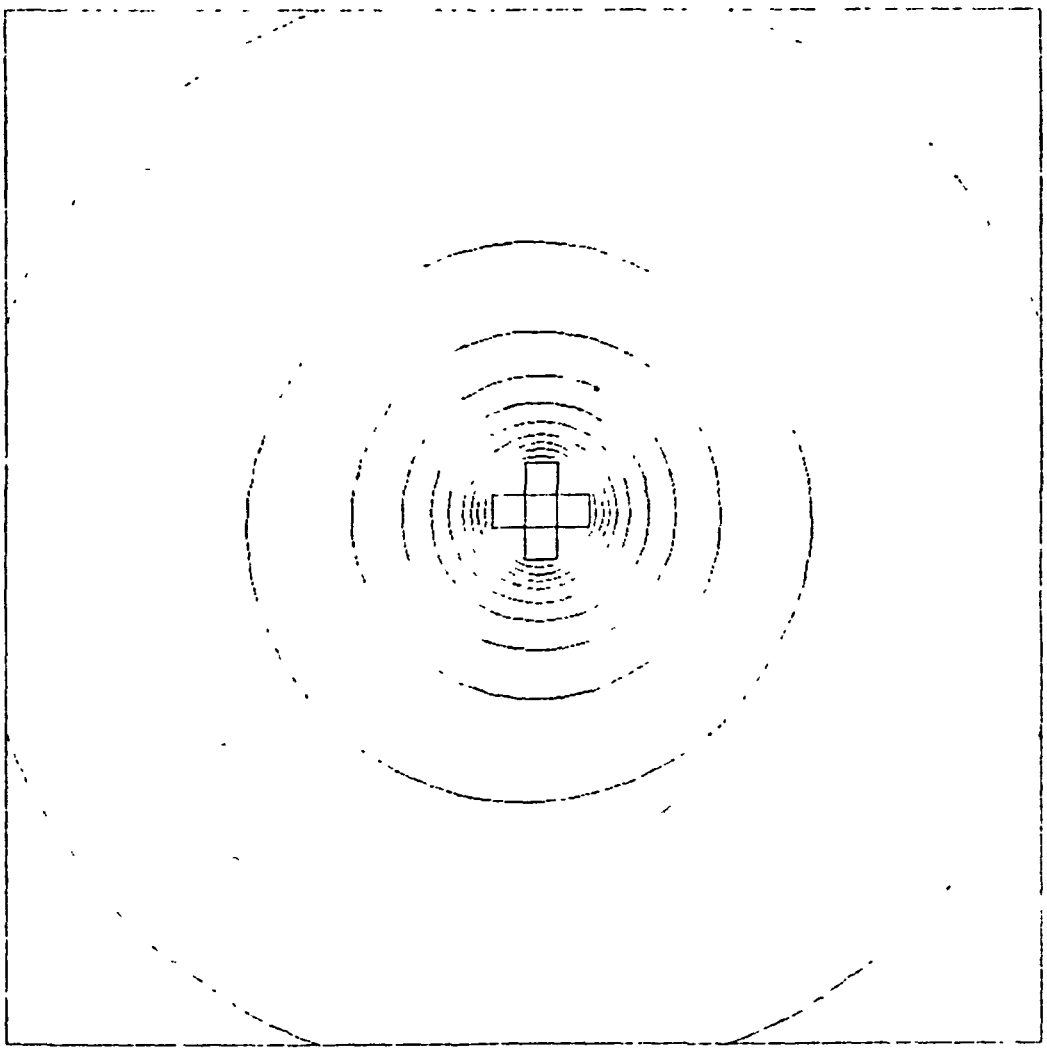


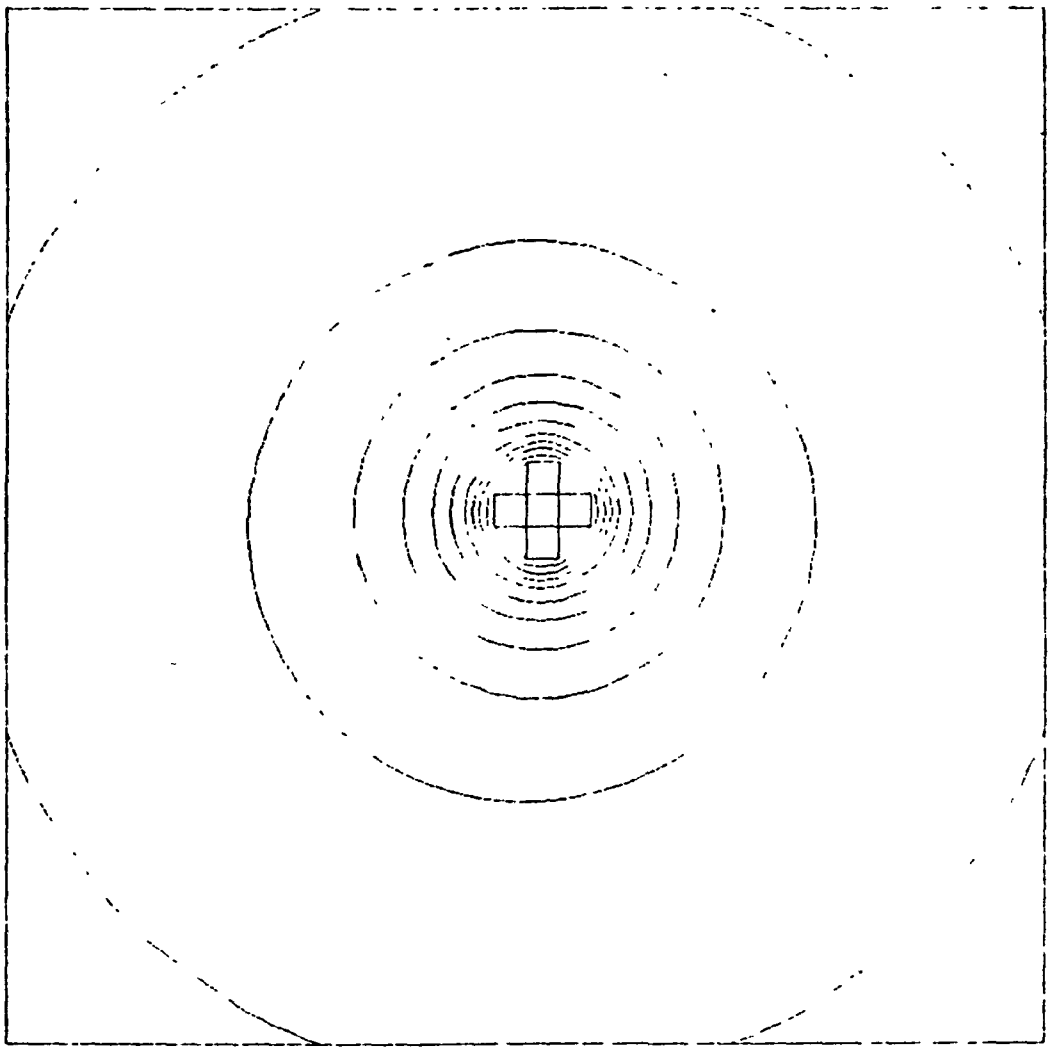
POTENTIAL CONTOURS ALONG THE X-Y PLANE OF Z = 9



POTENTIAL CONTOURS ALONG THE X-Z PLANE OF Y = 9



POTENTIAL CONTOURS ALONG THE Y-Z PLANE OF X = 9



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5. MAIN, MISCELLANEOUS AND UTILITY ROUTINES

In this section are described the main program, NASCAP, the sub-main program, TRILIN, their subsidiary routines, and various utility routines used in the NASCAP code.

5.1 MAJOR ROUTINES (NASCAP, TRILIN)

NASCAP

Purpose: NASCAP is the main routine. All other subroutines are called either directly or indirectly by NASCAP.

Internal Organization: (See flowchart, Figure 5.1.) NASCAP calls INOPT to read the runstream input file defining the grid, logical unit numbers and execution options.

If the input options call for any of the available plots, a flag is set to specify opening and closing of the plot output file at the appropriate time.

IOBCAL is checked: If IOBCAL is non-zero, OBJDEF is called to read satellite definition input and define the satellite. If IOBCAL is zero, the satellite has been defined by a previous run and OBJDEF is not called. In this case, OBJDEF output data required at this point is read from file IPLOT = IABS(IOBPLT), and this file is rewound.

If any plots were called for, a plot file is opened. If satellite illustration plots were requested, SATPLT is called to generate all three types of plots.

If a shadowed area calculation is requested for this run (IAREA > 0), HIDCEL is called to calculate the areas and generate the corresponding hidden-line plot.

If IOBCAL equals -1, this run is solely for object definition and plotting; solution of the problem is skipped.

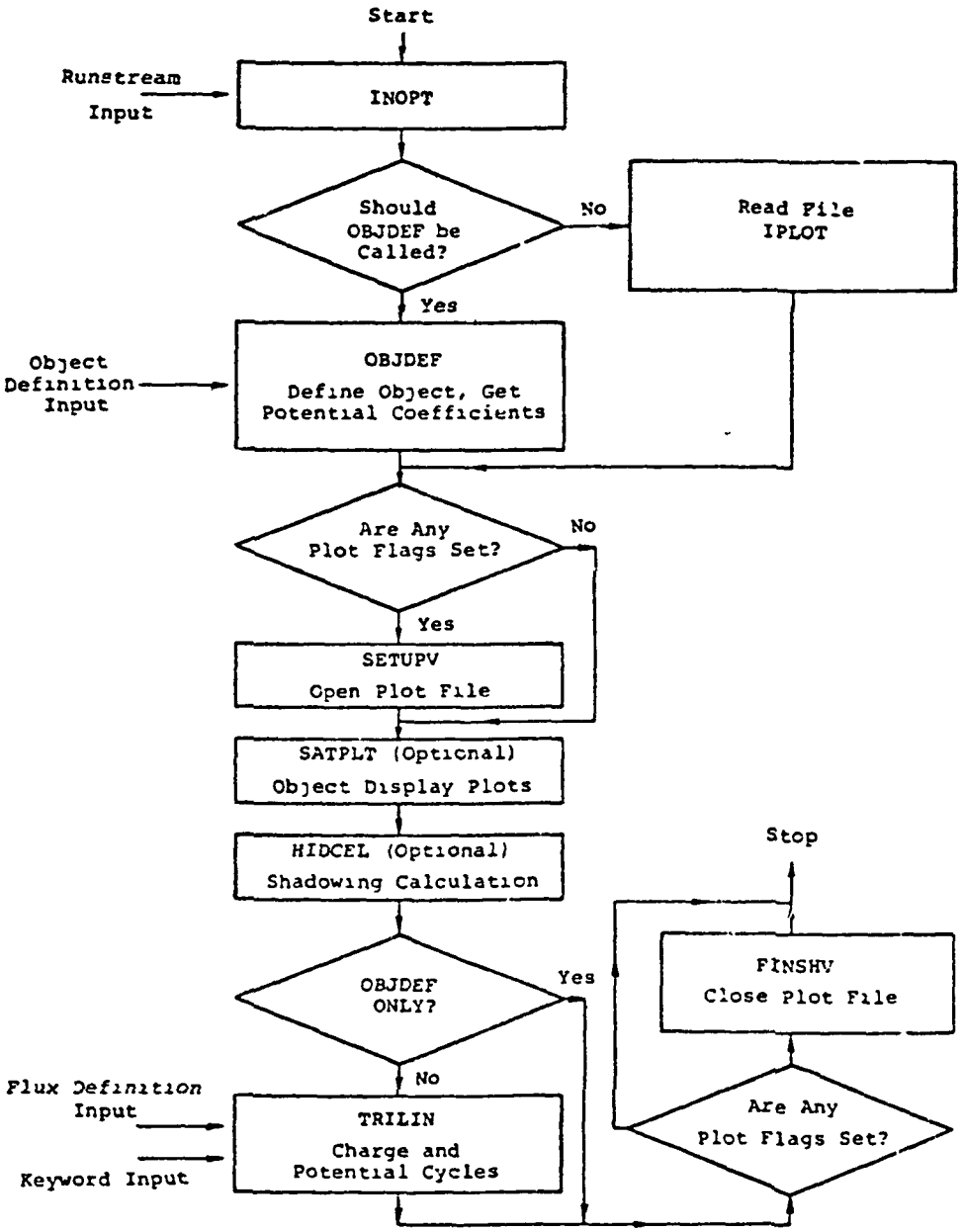

Figure 5.1. NASCAP flow chart.

Otherwise, subroutine TRILIN is called to cycle through the appropriate number of time steps, charging up the satellite, pushing particles, and solving potentials.

Upon return from TRILIN, if a plot file has been opened, it is closed and execution terminates.

TRILIN

Internal Organization: (See flowchart, Figure 5.2.) After calling FLXDEF and INDATA for initialization purposes, serves as primary program for NASCAP main loop: alternate calls to CHARGE and POTENT. Calls necessary routines for potential scaling, potential convergence plots and potential contour plots. After end of main loop, calls routines for restart dump, particle trajectory plots and charge density contour plots.

Called By: NASCAP

5.2 I/O ROUTINES

APRT

Purpose: APRT prints NGP grids' worth of data for the NX x NY x NZ x NG array stored on file IF.

Calling Sequence: SUBROUTINE APRT (BUF1, IF, NGP, NX, NY, NZ, NG)

Called By: POTENT (most calls are currently commented out), INDATA

Local Variables:
- IF: Unit number of file containing data to be printed.
- NGP: Number of grids' worth of this data to be printed.

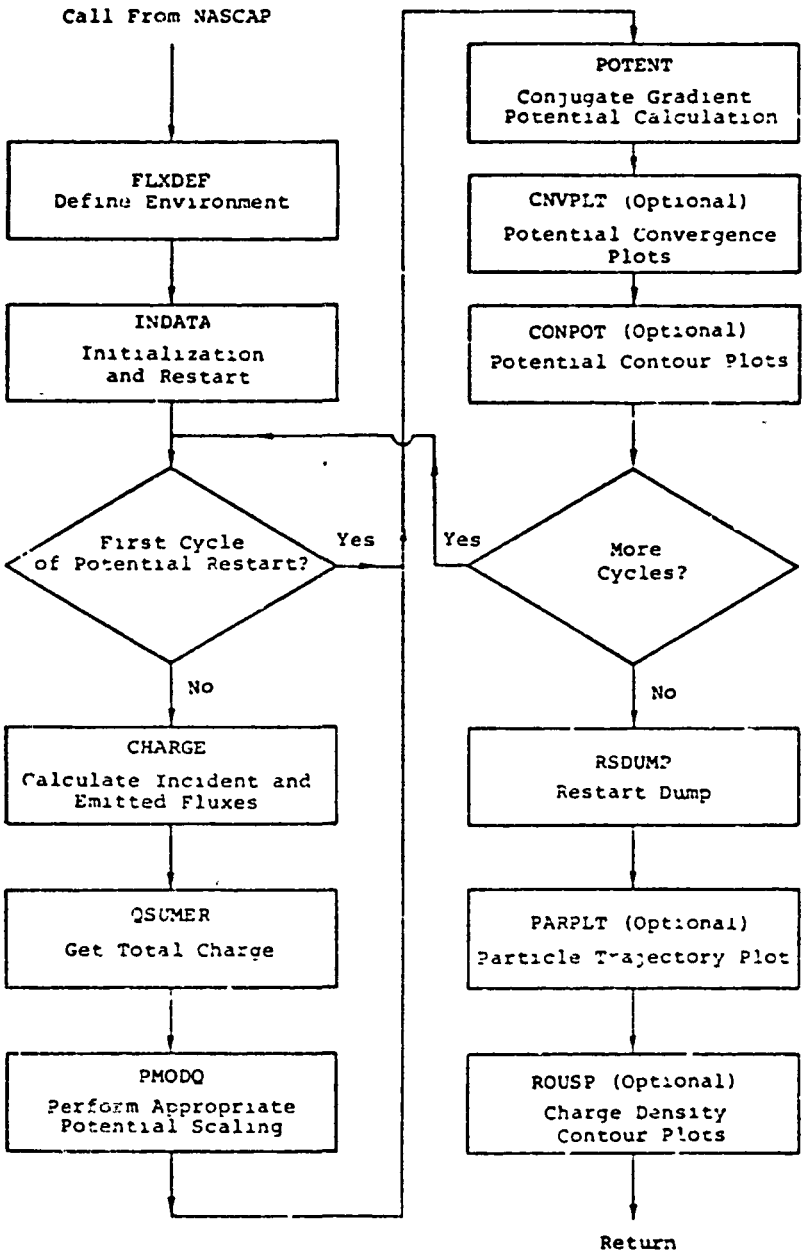

Figure 5.2. TRILIN flow chart.

FLXDEF

Purpose: Reads and preprocesses flux definition parameters.

Calling Sequence: SUBROUTINE FLXDEF (ITYPE1, NX, NY, NZ, NG)

Called By: TRILIN

GETNC

Purpose: Extract NC, the highest conductor index in problem, from JSURF(NSURF).

Calling Sequence: SUBROUTINE GETNC(NC)

Called By: INDATA

INDATA

Purpose: Performs data manipulations associated with initialization/restart.

Calling Sequence: SUBROUTINE INDATA (NX, NY, NZ, NG, NC)

Called By: TRILIN

INKEYW

Purpose: Reads "keyword" input file and sets up associated options.

Calling Sequence: SUBROUTINE INKEYW (IKEY)
IKEY - LUN of keyword input file.

Called By: INDATA

LORDER

Purpose: Puts in numerical order LIST(1) entries starting at LIST(2). If W(1) $\neq$ 0.0, array W parallels LIST(2)... LIST(LIST(1)+1) and will be reordered similarly. (Identical routine LORDEQ is called by OBJDEF.

Calling Sequence: SUBROUTINE LORDER (LIST, W)

Called By: INKEYW

INOPT

Purpose: INOPT reads the runstream input file (corresponding to card input) which defines the grid limits, logical unit numbers, restart, plot and execution options, potential iteration limits, the time cycle limits and timestep.

INOPT prints out all of these data at the start of NASCAP printed output.

Calling Sequence: SUBROUTINE INOPT (NX, NY, NZ, NG, NC, MAXIDF, PEPSDF)

Called By: NASCAP

MOVDAT

Purpose: MOVDAT is the general data movement subroutine used throughout the code to block transfer large quantities of data between external storage files and internal code storage arrays.

Calling Sequence: SUBROUTINE MOVDAT (N, DAT, IUNIT, IN)

Called By: (All routines doing block-transfer I/O)

CHARGE	PUPDAT	QSUMER
HIDCEL	RUPDAT	SETALL
OBJDEF	UDOTUC	
POTENT	YUPDAT	
TRILIN	UUPDAT	
ROUSP	UUPDAU	
OBJSPC	QCONCP	
URSETO	SETOP	
YINIT	PMODQ	

Local Variables:

N: Number of words to be transferred.

DAT: Core storage array data is to be moved into or out of.

IUNIT: Logical unit number of file to be read or written onto.

IN: IN = 1 implies read from file into DAT; IN = 0 implies write from DAT onto file.

REWIND

Purpose: REWIND rewinds file IUNIT by executing the block-transfer (NTRAN) rewind command. For block-transfer files, the regular FORTRAN rewind cannot be used.

Calling Sequence: SUBROUTINE REWIND (IUNIT)

Called By: (All routines doing block-transfer I/O)

CHARGE	RUPDAT
HIDCEL	UDOTUC
OBJDEF	YUPDAT
POTENT	UUPDAT
TRILIN	UUPDAU
ROUSP	QCONCP
OBJSPC	SETOP
URSETO	PMODQ
YINIT	QSUMER
PUPDAT	SETALL

Local Variables: IUNIT: Logical unit to be rewound.

RSDUMP (See INDATA)

Purpose: Prepares files for possible future restart.

Calling Sequence: SUBROUTINE INDATA (NX, NY, NZ, NG, NC)
ENTRY RSDUMP (NX, NY, NZ, NG, NC)

Called By: TRILIN

SUMQD

Purpose: Used for "DSCALE" option. Calculates (and prints)

$$QSUMD = QSUM - \sum_{\substack{\text{fixed} \\ \text{conductors}}} QCOND(I_{fixed})$$

Calling Sequence: SUBROUTINE SUMQD (QSUMD, QSUM, QCOND, NC)

Called By: TRILIN

5.3 POTENTIAL SCALING AND RELATED ROUTINES

PMODQ

Purpose: Scales potentials in accordance with total charge on object.

Calling Sequence: SUBROUTINE PMODQ (BUF1, IP, ISPARE, PCOND, NX, NY, NZ, NG, QSUMO, QSUM)

Called By: TRILIN

QSUMER

Purpose: Calculates total charge contained within inner grid.

Calling Sequence: SUBROUTINE QSUMER (IROUS, ROUS, QCOND, NX, NY, NZ, QSUM)

Called By: TRILIN, INDATA

RESETQ

Purpose: Scales all potentials and charges by 10**IOUTER. Called for ICREST = 0, IPREST = 1, IOUTER < 0.

Calling Sequence: SUBROUTINE RESETQ (NX, NY, NZ, NG, Q)

Called By: INDATA

SETALL

Purpose: Called when IPREST = ICREST = 0, IOUTER = 2 to set all potentials to $Q/4\pi r$.

Calling Sequence: SUBROUTINE SETALL (NX, NY, NZ, NG, Q)

Called By: INDATA

SETIP

Purpose: For IOUTER = 0 or 1, SETIP writes the initial guess potentials for the innermost grid (zeroes, in these cases) onto file IP.

Calling Sequence: SUBROUTINE SETIP (BUF1, IP, NX, NY, NZ, NG)

Called By: INDATA

SETOP

Purpose: After the innermost grid data for the initial guess potentials have been placed on file IP by SETIP, SETOP is called to fill in the data for all remaining grids.

Grids 2 through NG-1 are zero-filled, and the outermost grid is either zero-filled (IOUTER = 0), or filled with the $1/4\pi r$ data generated by SETPOP for its outer edges (IOUTER = 1).

Calling Sequence: SUBROUTINE SETOP (BUF1, BUF2, IP, NX, NY, NZ, NG)

Called By: TRILIN
INDATA
SETOP is called only when IOUTER = 0 or 1.

SETPOP

Purpose: For IOUTER = 1, SETPOP defines the initial guess potentials on the outer edges of the outer grid according to Coulomb's law:

$$P = Q/4\pi r$$

Potentials not on the outer edge of the outer grid are set to zero for this case.

Calling Sequence: SUBROUTINE SETPOP (P, QSUM, NX, NY, NZ)

Called By: TRILIN

Local Variables: P: Storage area BUF1, representing outer grid initial guess potentials.

5.4 CNVPLT AND PRINTER-PLOTTER

CNVPLT

Purpose: Plots potential convergence parameters using printer-plotter routines, i.e., ALOG10(R(I)) versus I, ALOG10(U(I)) versus I, P(I) versus I.

Calling Sequence: SUBROUTINE CNVPLT (R, U, P, NI)

R(NI) - An array of positive numbers.

U(NI) - An array of positive numbers.

P(NI) - An array assumed to contain potentials of spacecraft ground.

NI - Dimension of arrays R, U, P.

Called By: TRILIN

DOPLOT

Purpose: Generates printer plot from data in COMMON blocks /PLOT/, /I0031/. (Part of printer plotter package.)

Calling Sequence: SUBROUTINE DOPLOT (ISYM)

ISYM(1) - array of symbols to be used in plot.

Called By: CNVPLT

INPLOT

Purpose: Initializes printer plot. (Printer plotter package.)

Calling Sequence: SUBROUTINE INPLOT (XMIN, XMAX, YMIN, YMAX, IBANDS)

XMIN, XMAX, YMIN, YMAX - axis limits of plot

IBANDS - length of plot in units of ten lines

Called By: CNVPLT

LINPLT

Purpose: Printer plotter routine. Plots point (X,Y) with symbol NUMSYM and straight line to previous point with symbol LINSYM.

Calling Sequence: SUBROUTINE LINPLT (X, Y, NUMSYM, LINSYM)

Called By: CNVPLT

OLDLIN (See LINPLT)

Purpose: Printer plotter package. This entry not currently used by NASCAP.

Calling Sequence: SUBROUTINE LINPLT (X, Y, NUMSYM, LINSYM)
Entry OLDLIN (X, Y, NUMSYM, LINSYM)

POINT

Purpose: Pringer plotter package. Plots point (X,Y) with symbol NUMSYM.

Calling Sequence: SUBROUTINE POINT (X, Y, NUMSYM)

Called By: CNVPLT

REPLOT (See INPLOT)

Purpose: Printer plotter package. This entry not used in NASCAP.

Calling Sequence: Entry REPLOT (XMIN, XMAX, YMIN, YMAX, IBANDS)

6. CODE DESCRIPTION - OBJECT DEFINITION SECTION

6.1 INTRODUCTION AND GENERAL CONSIDERATIONS

6.1.1 Function

The OBJDEF section of the NASCAP code serves to translate relatively simple user specifications of geometrical shapes, surface composition and material properties into the far more complex information required for efficient operation of the POTENT, CHARGE, HIDCEL and SATPLT sections. The user input to OBJDEF is read from file ISAT, which is described in Section 6.2. In addition to printed output (described in Section 6.3), OBJDEF generates files IOBJ (for use by POTENT) and IOBPLT (for use by CHARGE, SATPLT and HIDCEL). The contents of these files is given in Section 6.4.

6.1.2 Volume Cells

The object to be simulated is defined on the inner cubic mesh. The "lower left-hand" corner of the inner mesh is at mesh point (1,1,1), while the "upper right-hand" corner is at (NX,NY,NZ). The object should be restricted to the space

$$2 \leq x \leq NX - 1$$

$$2 \leq y \leq NY - 1$$

$$2 \leq z \leq NZ - 1,$$

i.e., it should not contact the edge of the inner grid. For convenience, coordinates are specified relative to an "OFFSET", which is initially set to the center of the mesh, and may be specified by the user using the "OFFSET" command (see below). An "OFFSET" of (0,0,0) will allow object definition in terms of "absolute" coordinates. A volume cell is referenced by

its lowest indexed corner. The physical distance corresponding to a grid unit is specified using the "MESH SIZE" command.

The object (as well as the space external to the object) is built of the four building blocks shown in Figure 6.1: the cube, the right prism or "WEDGE", the tetrahedron, and the complement of a tetrahedron. Of course, the user is not required to define an object cell by cell, but in terms of larger geometrical components (Figures 6.2-6.13):

1. The rectangular parallelepiped ("RECTAN"), defined by a corner coordinate and three edge lengths. (Object 1 on Figures 6.2-6.13.)

2. The right prism ("WEDGE"), defined by a corner coordinate, two lengths and an orientation. (Object 5 on Figures 6.2-6.13.)

3. The tetrahedron ("TETRAH"), defined by a corner coordinate, a length and an orientation. (Object 3 on Figures 6.2-6.13.)

4. The "FIL111" object, a special type of wedge described in Section 6.2.7. (Teflon-coated portion of object 6 on Figures 6.2-6.13.)

5. The octagonal right cylinder ("OCTAGO"), a complex object formed of two "RECTAN"s and four "WEDGE"s, defined by the ends of its axis, its width and its side. (Object 4 on Figures 6.2-6.13.)

6. The quasisphere ("QSPHER"), a multiply complex object formed of three "OCTAGO"s and eight "TETRAH"s, defined by its center, diameter and side. (Object 2 on Figures 6.2-6.13.)

Detailed input specifications for each of the above objects are given in Section 6.2.

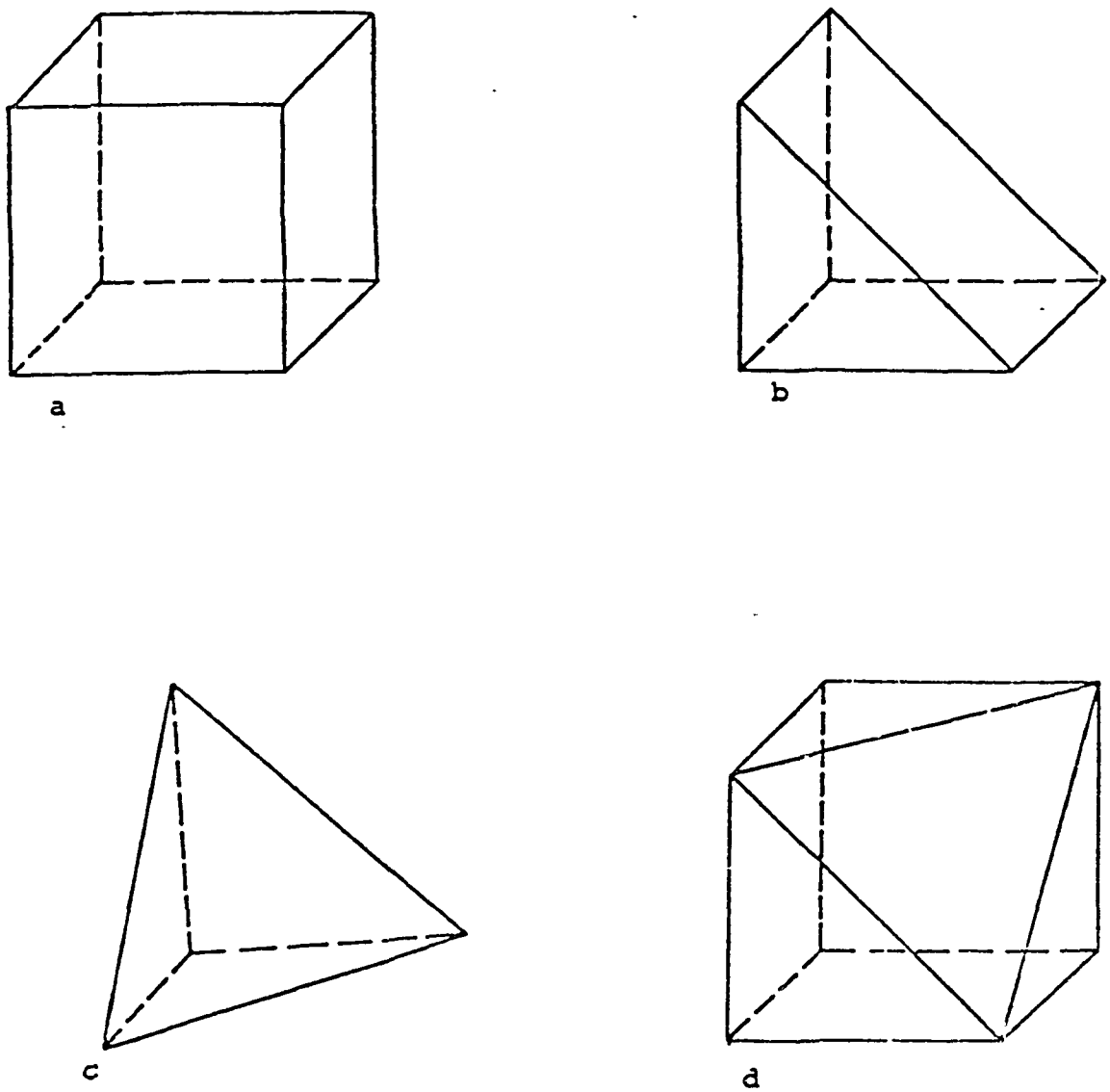

Figure 6.1. Four shapes of volume cells considered by the NASCAP code: (a) empty cube; (b) wedge-shaped cell with 110 surface; (c) tetrahedron with 111 surface; (d) truncated cube with 111 surface.

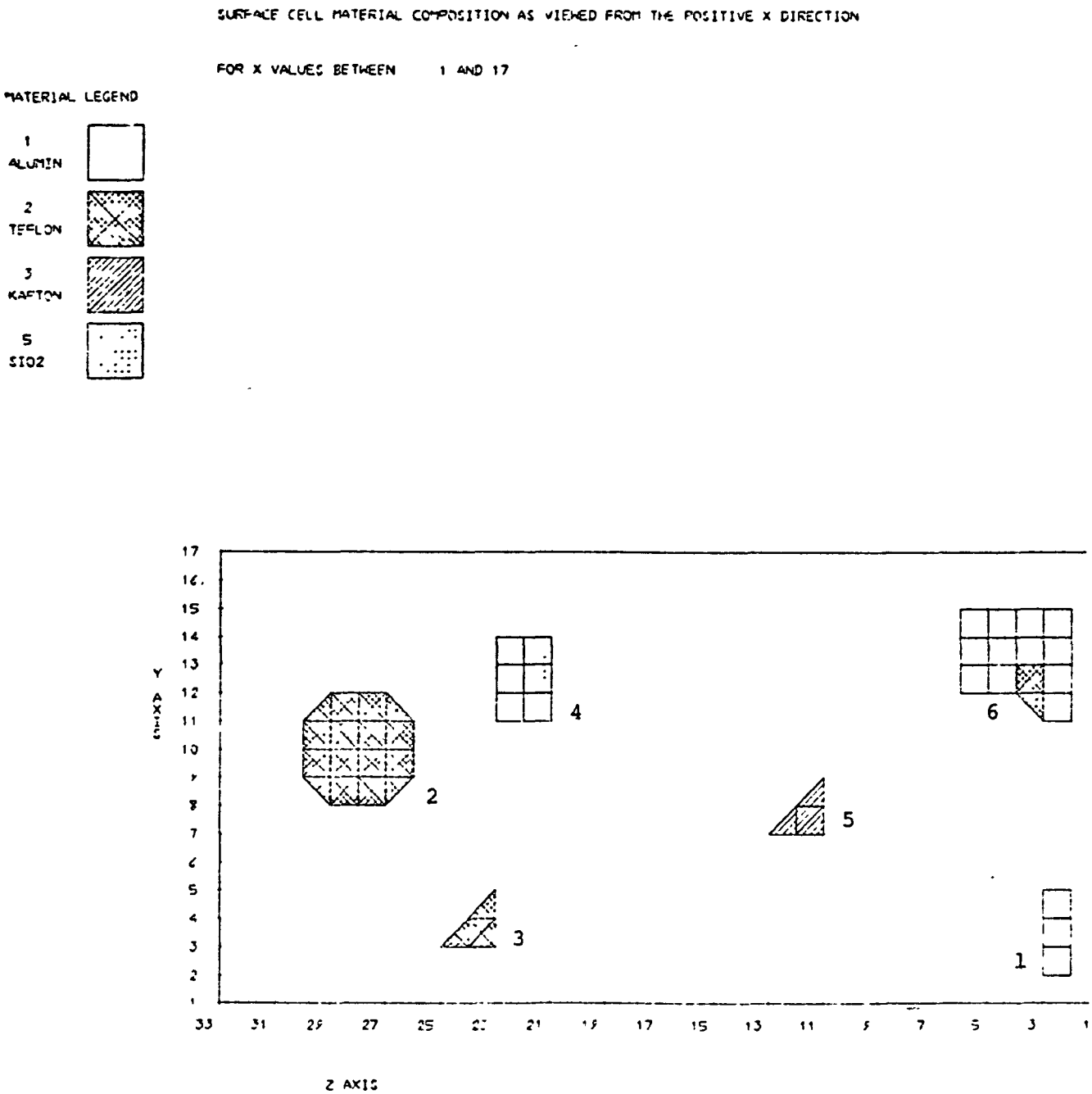

Figure 6.2. Illustration of NASCAP object definition. Non-perspective view showing surface cell compositions. (1) rectangular parallelepiped; (2) quasi-sphere; (3) tetrahedron; (4) right octagonal cylinder; (5) right triangular prism; (6) compound object consisting of aluminum rectangular parallelepiped, aluminum right triangular prism, and teflon <111> wedge.

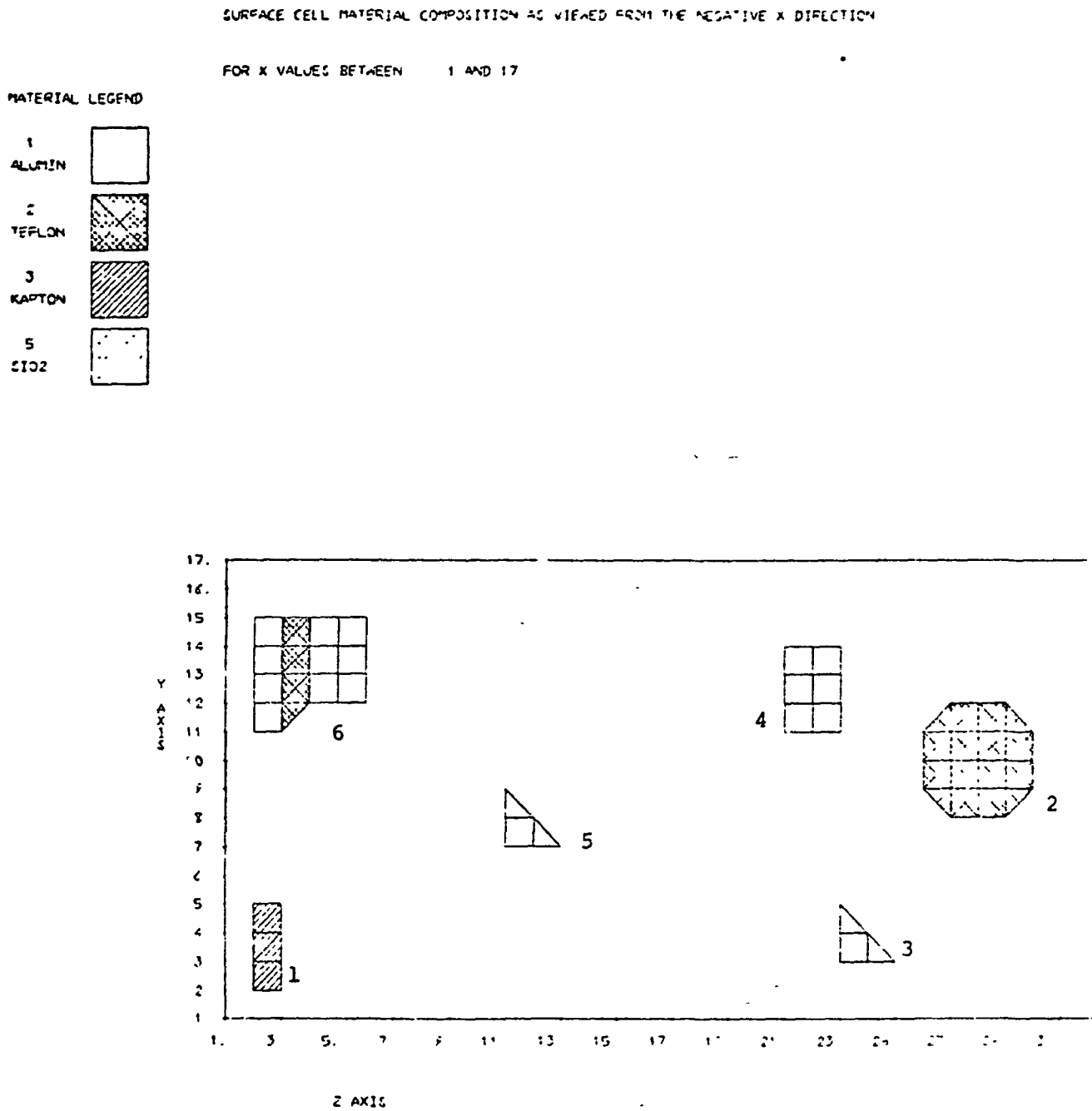

Figure 6.3. Another view of Figure 6.2.

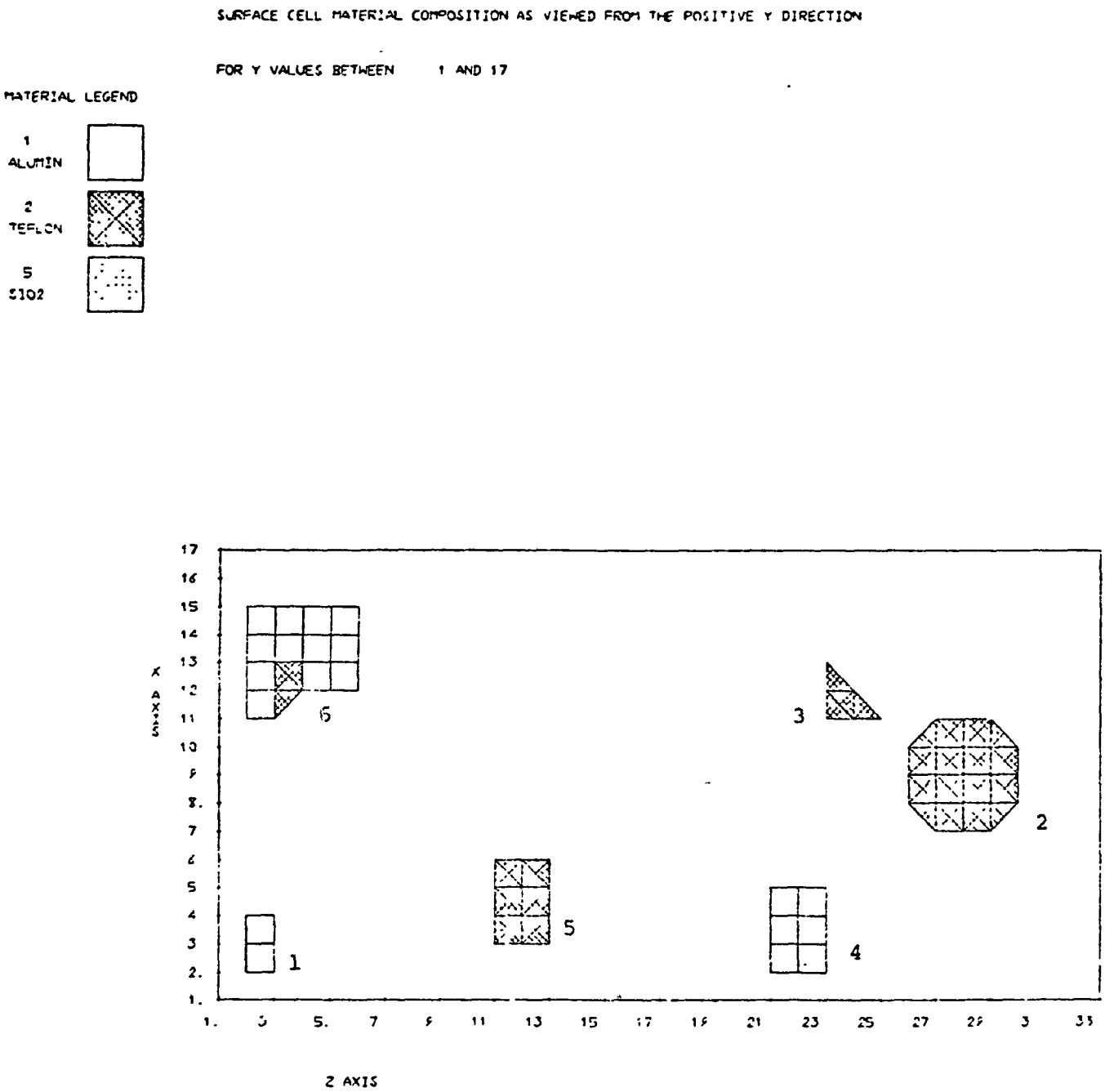

Figure 6.4. Another view of Figure 6.2.

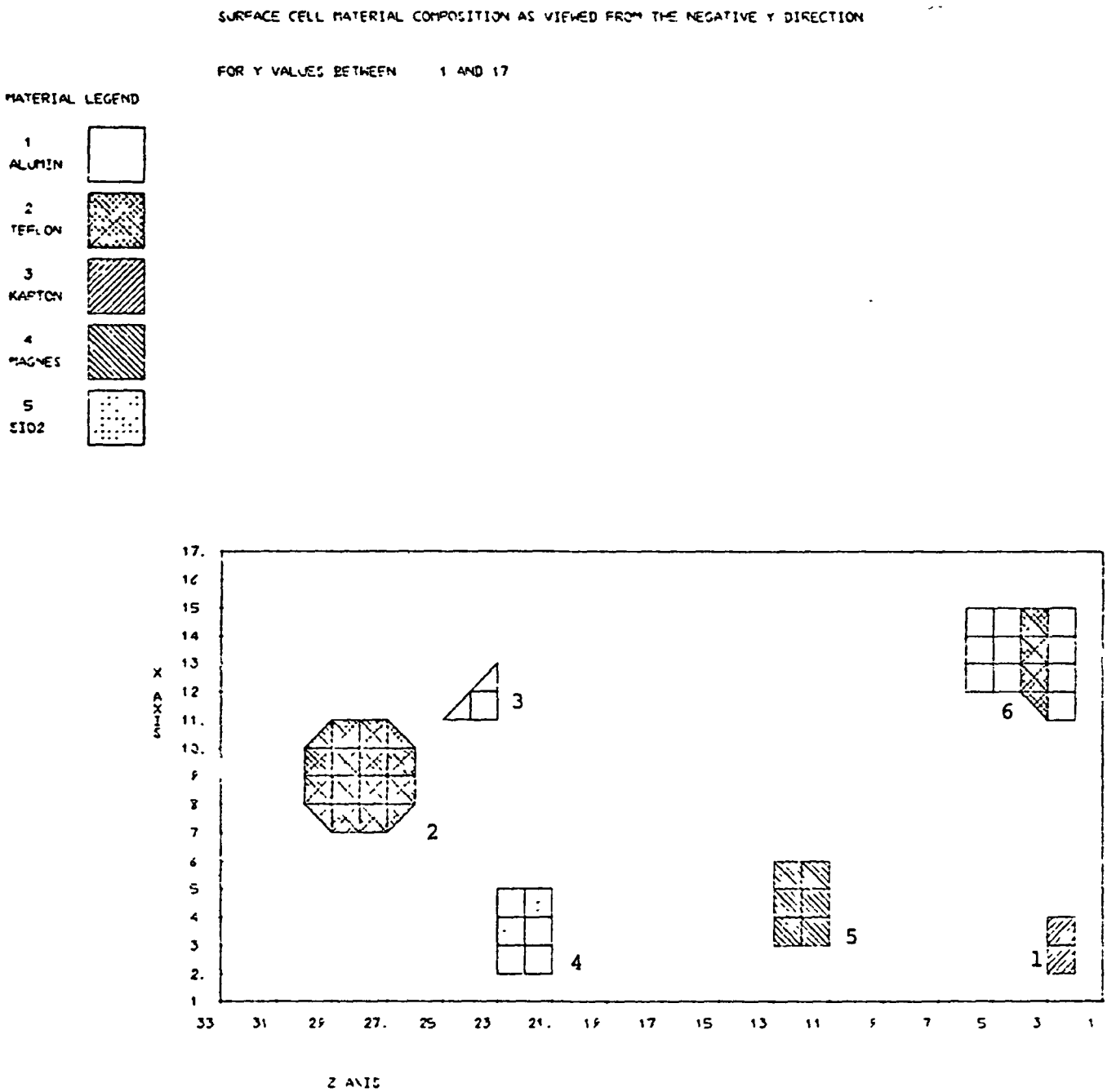

Figure 6.5. Another view of Figure 6.2.

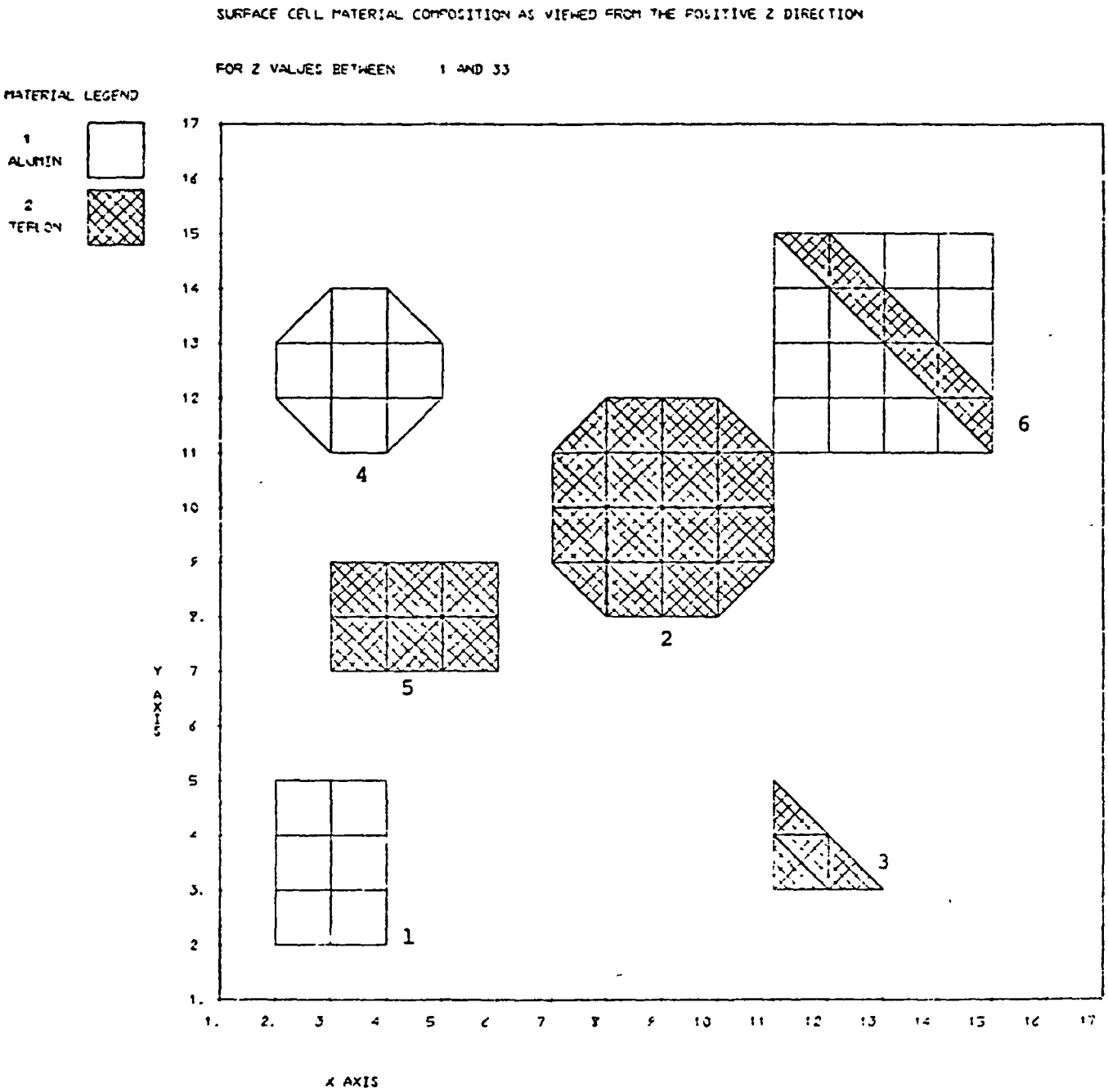

Figure 6.6. Another view of Figure 6.2.

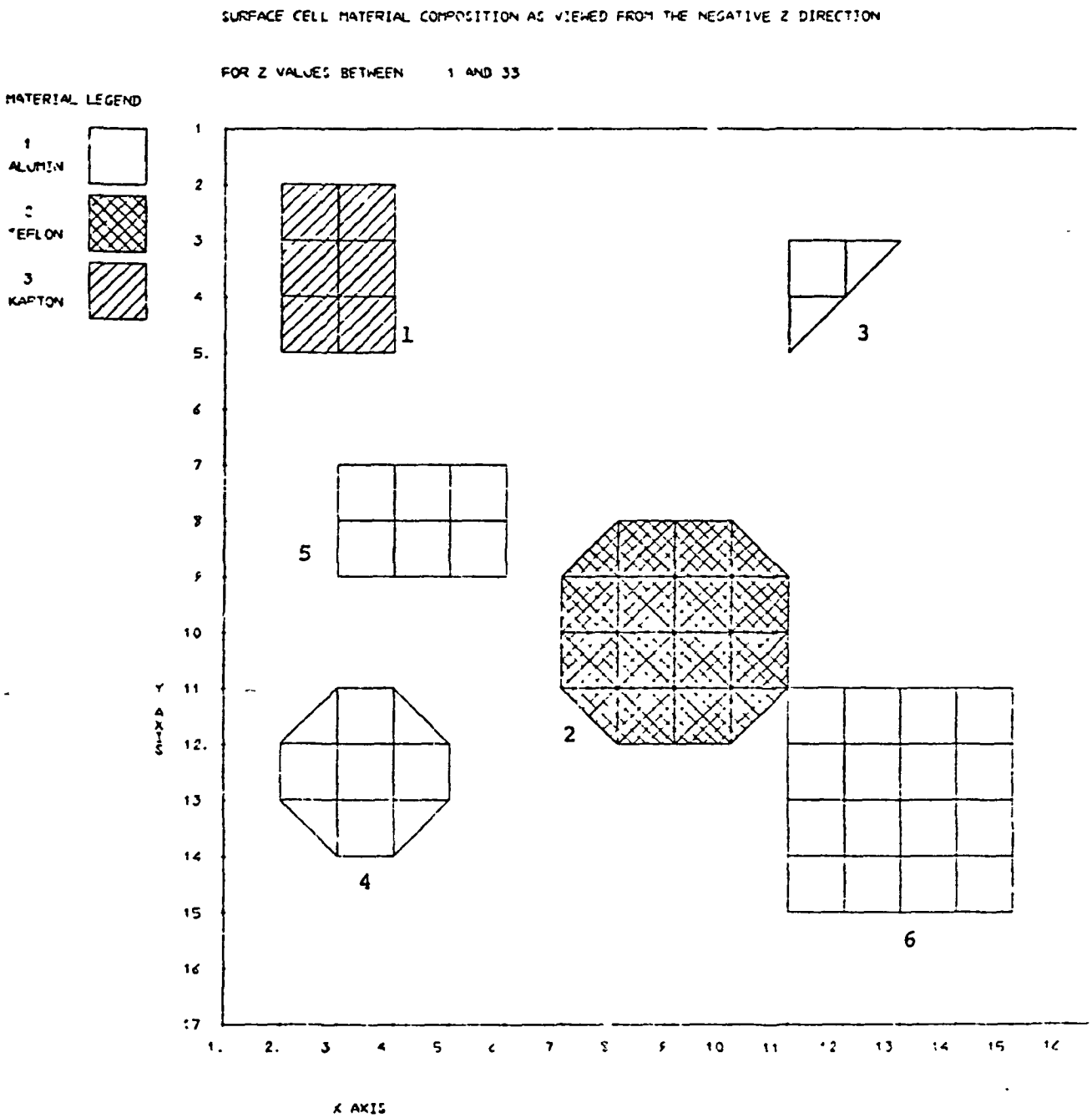

Figure 6.7. Another view of Figure 6.2.

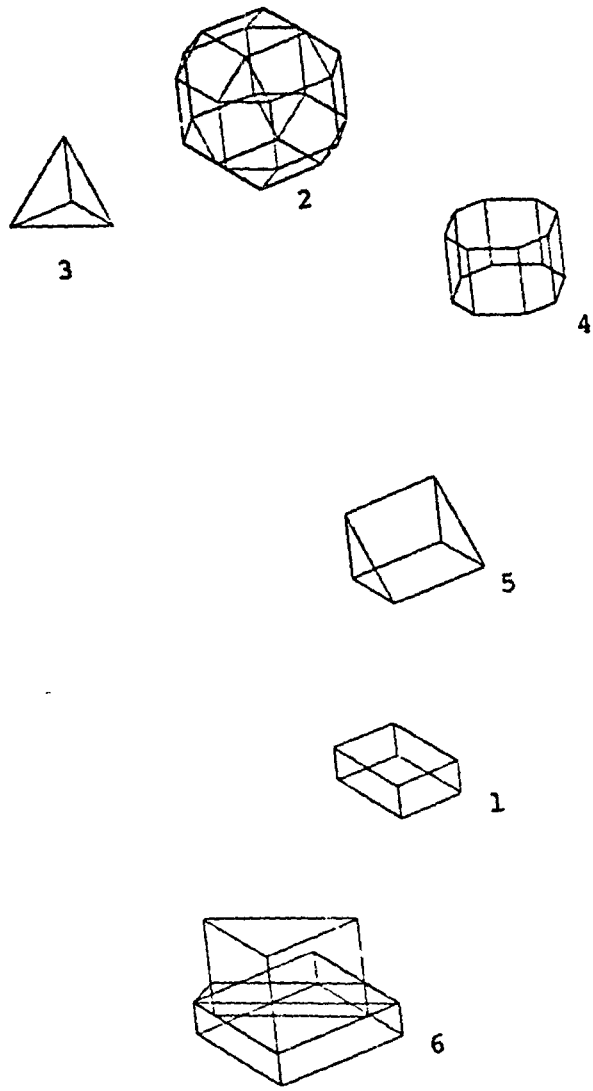

Figure 6.8. A perspective view of the six objects in Figure 6.2; no hidden line elimination.

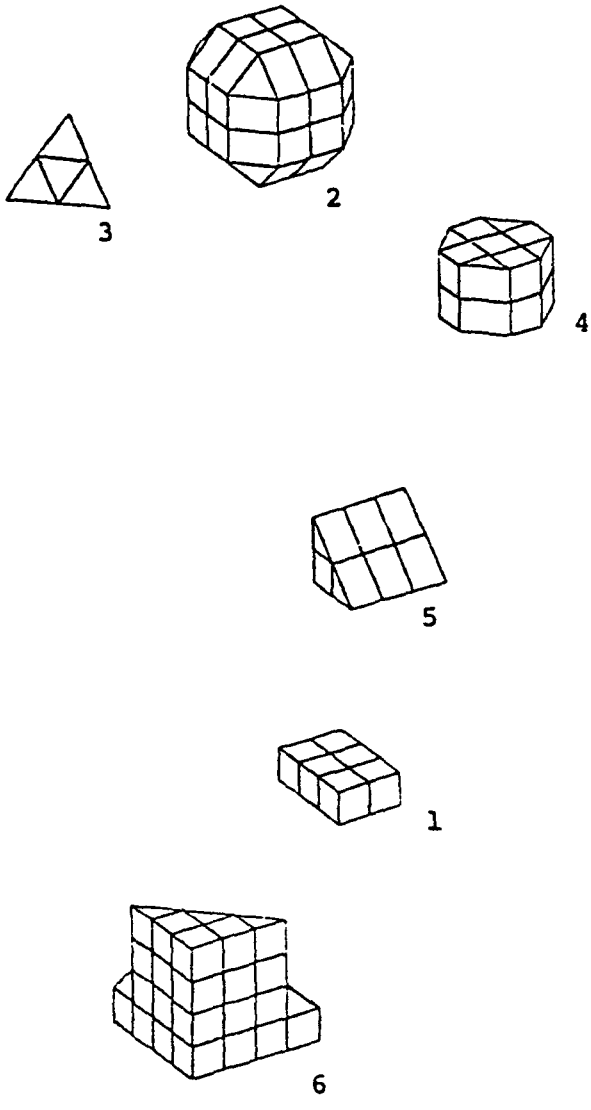

Figure 6.9. The same as Figure 6.8, but with hidden line elimination and showing surface cells.

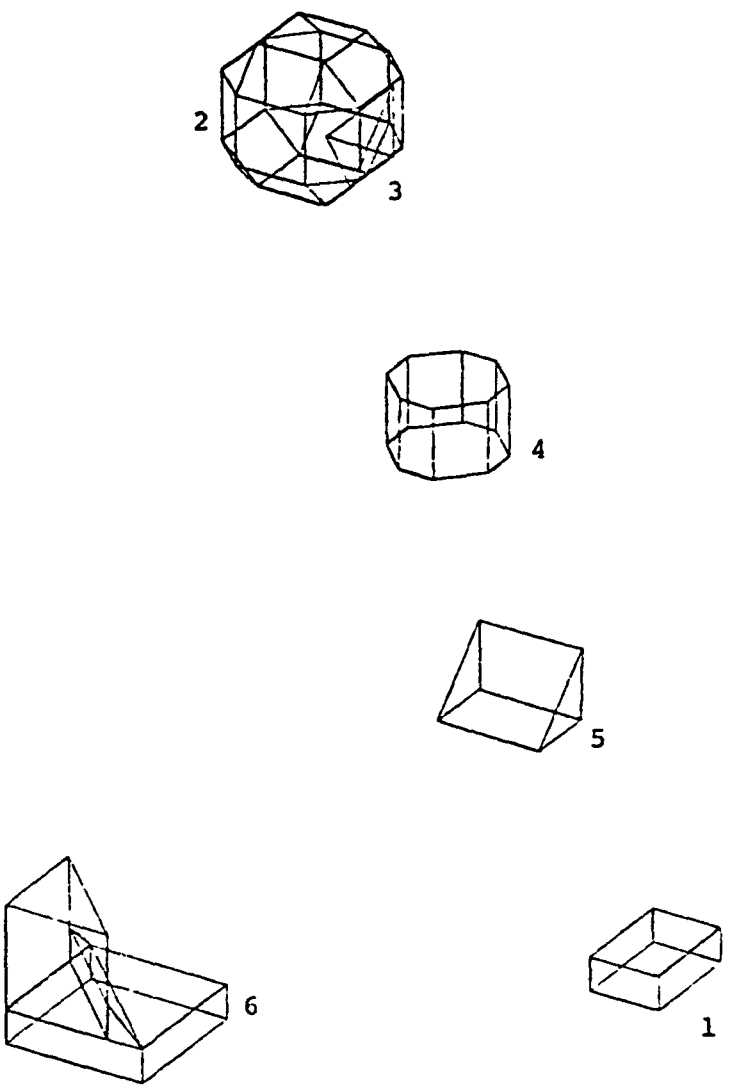

Figure 6.10. Another view of Figure 6.8.

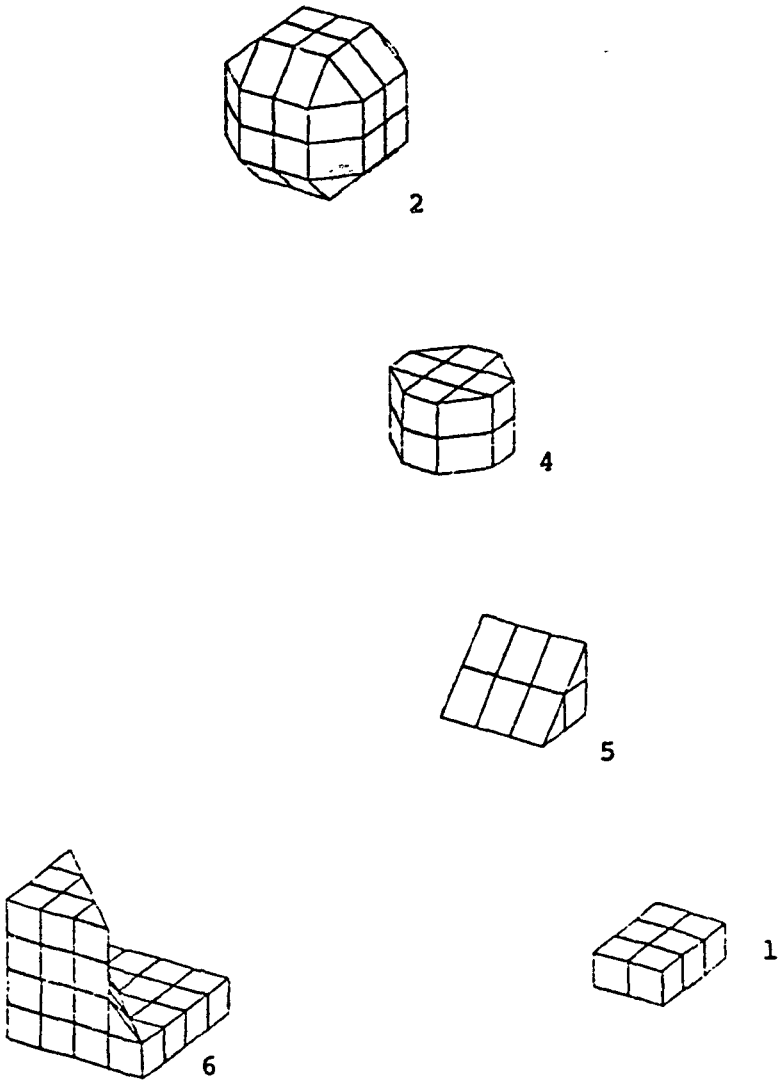

Figure 6.11. The same as Figure 6.10, but with hidden line elimination and showing surface cells.

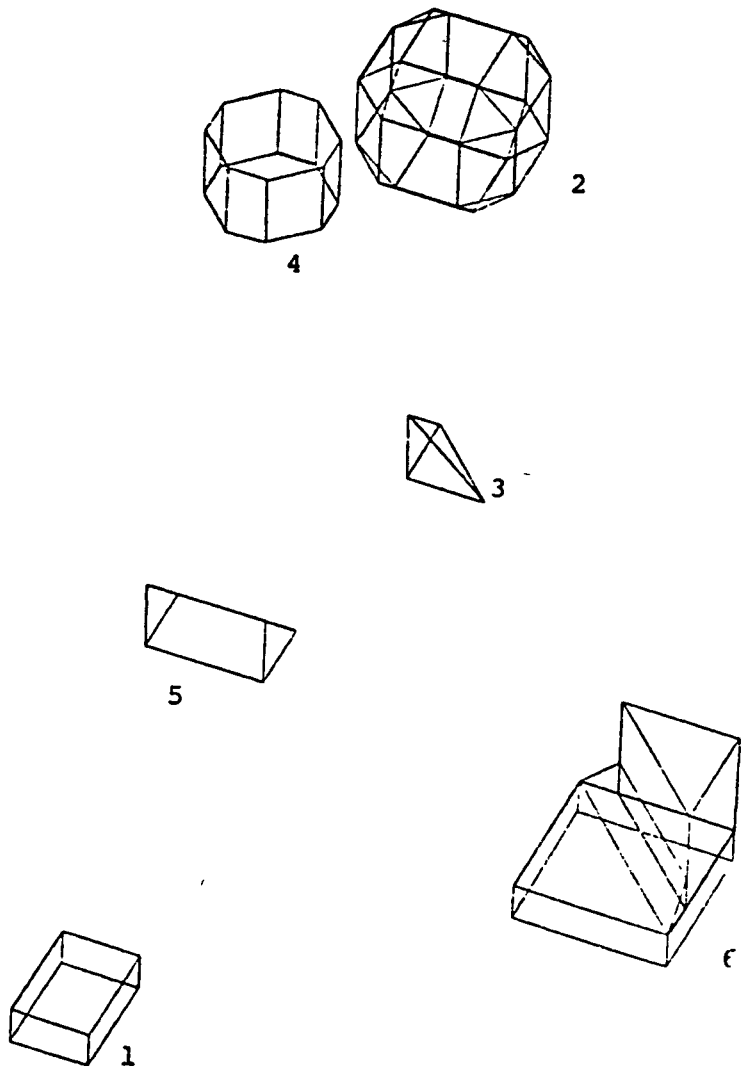

Figure 6.12. Another view of Figure 6.8.

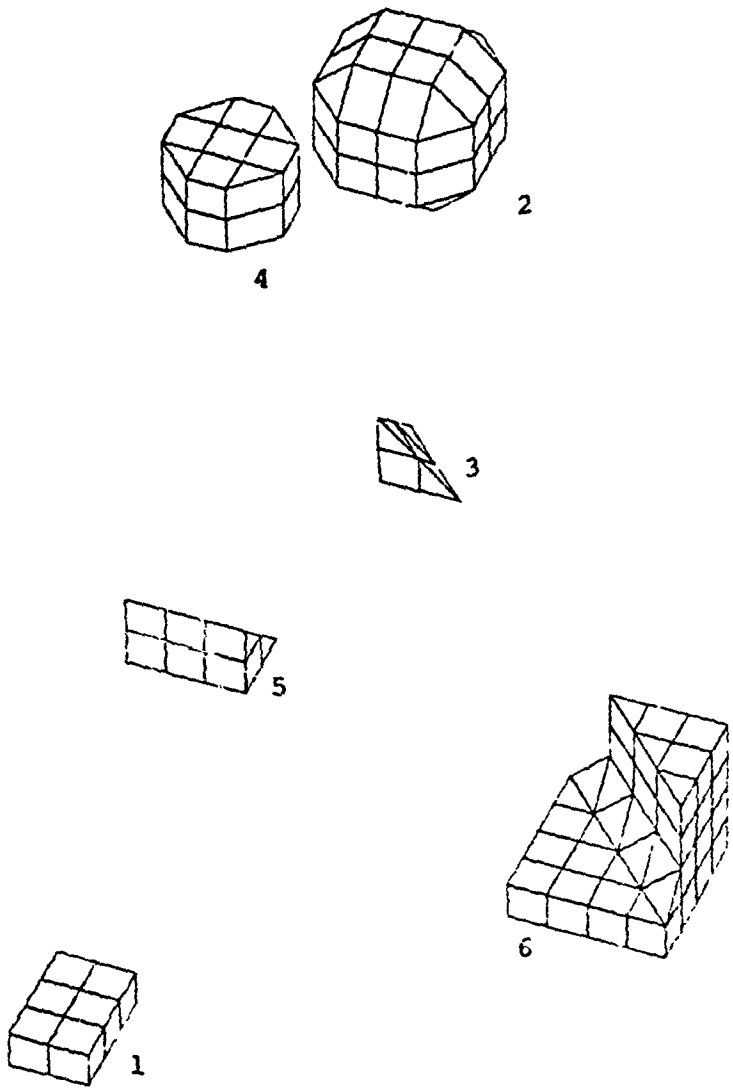

Figure 6.13. The same as Figure 6.12, but with hidden line elimination and showing surface cells.

6.1.3 Surface Cells

The four types of volume cells give rise to five distinct types of surface elements, or surface cells. A surface cell is identified by (1) the volume cell within which it is located, or out of which its normal points, and (2) the direction of its outward normal. The latter is conveniently expressed in crystallographic notation: (100), $(10\bar{1})$, etc., and the divisions of these directions into different symmetry classes provide a primary categorization of surface cell types. The surface cell types are:

(100): a. simple square, size 1 x 1 (mesh units);

b. right isosceles triangle, which must be further identified by the location of its right-angle corner;

(110): rectangle 1 x $\sqrt{2}$ (mesh units) associated with wedge cell;

(111): equilateral triangle of side $\sqrt{2}$ (mesh units); there are two types of such cells, depending on whether the associated volume cell is (a) 1/6 full and 5/6 empty, or (b) 5/6 full and 1/6 empty.

In addition to its type and location, a surface cell is labeled as to material composition and as to the conductor it overlays. NASCAP's internal surface cell code format is shown in Figure 6.14.

A maximum of 1024 surface cells is allowed by NASCAP. Definition of superfluous surface cells is automatically bypassed. Surface cells that become superfluous after their definition may be eliminated by the "COMPRE" command, initiating a call to subroutine CMPRSS. (CMPRSS is automatically called following the 'ENDSAT" command or an EOF on unit ISAT.) In case of a multiply-defined surface cell, the latest definition supersedes the earlier.

```
5 43 210 987654 321098 765432 109876 5 43210
 |_| |_| |______| |______| |______| |______| | |_____|
  H   G     F        E        D        C     B    A
```

Field	Bits	
A	4-0	Material index
B	5	Set for right-triangular 100 surfaces and for 111 surfaces whose enclosing volume cell is mostly empty.
C	11-6	Direction of surface normal (in crystallographic notation)
D	17-12	Z-coordinate
E	23-18	Y-coordinate
F	29-24	X-coordinate
G	32-30	Conductor index
H	34-33	Orientation code for right-triangular 100 surfaces.

Figure 6.14. Surface element list (JSURF) entry format.

6.1.4 Special Cells, Surface Points, Special Points, Multiple Conductors

A volume cell is labeled as a special cell if a potential interpolation formula other than the usual trilinear one must be used; i.e., if it is partially filled or if a right triangle surface cell points into it. The element table, LTBL (NX,NY,NZ), (see Figure 6.15), is set up by the OBJDEF section for use elsewhere to identify special cells.

A point is a surface point if it is a vertex of a surface cell. A surface point is a multiconductor point if it is a vertex of surface cells overlaying different conductors.

Conductors are numbered 1 < IC < 7 using the "CONDUC" command (q.v.). Conductor 1 is usually considered spacecraft ground. (See Keyword Input, Section 2.4.)

A vertex of a special cell which is not a surface point is a special point.

6.1.5 Restrictions on Object Geometry

1. No surface point or special point may lie on the mesh boundary. It follows that all surfaces must be at least one unit removed from the mesh boundary, and a right triangle surface cell must be at least two units from the mesh boundary toward which it points.
2. A maximum of 1024 surface cells is allowed.
3. No volume cell can have two or more right-triangle surface cells pointing into it.
4. A partially filled volume cell cannot be superseded by another partially filled cell except through use of the "DELETE" command (q.v.).

Code for Element Table [LTBL(NX,NY,NZ)].

```
54321 0987654321 0 9 8 765 432109876 5 43210
      └──────────┘   │ │   └────────┘   └────┘
            E        D C        B         A
```

Field	Bits	
A	4-0	Cell-type code (see Appendix D)
B	14-6	Orientation code (see Appendix D)
C	18	Set if cell is completely filled (interior)
D	19	Set for an empty special cell
E	30-21	Index used to reference PHOJ array to determine low energy electron currents

ORIENTATION CODE

3x3 bits. Each group of 3 contains 1, 2 or 3 in the lower 2 bits, with the high bit set for negative.

$$\text{Code } \left[(-)^{m_1} i_1,\ (-)^{m_2} i_2,\ (-)^{m_3} i_3\right]$$

$$\text{takes } (r_1, r_2, r_3) \text{ to } \left[(-)^{m_1} r_{i_1},\ (-)^{m_2} r_{i_2},\ (-)^{m_3} r_{i_3}\right]$$

e.g., the following codes take a point to (x,y,z):

Octal Code	Dec. Code	Point
123	1,2,3	(x,y,z)
365	3,-2,-1	(-z,-y,x)
532	-1,3,2	(-x,z,y)
176	1,-3,-2	(x,z,-y)
567	-1,-2,-3	(-x,-y,-z)
617	-2,1,-3	(y,-x,-z)

Figure 6.15. Element table codes and orientation codes.

6.2 INPUT SPECIFICATIONS

6.2.1 General Considerations

User input to the object definition section of NASCAP is read from file ISAT primarily by subroutine INPUT and secondarily by subroutines RECTAN, OCTGON, WEDGE, FIL111, QSPHER and TETRAH. The action taken by INPUT in response to a record is determined by a literal in columns 1-6. Recognized literals are indicated in Table 6.1. If the literal is an object name, one of the above subroutines will be called and will expect further input (see below). Control will be returned to INPUT upon encountering an "ENDOBJ" or "ENDSAT" card. If the literal is recognized to be a command, the corresponding data (if any) will appear on the same card. An unrecognized literal is assumed to be a material name and must be followed by three cards containing material parameters (FORMAT 8F10.0) (see Section 6.5).

As an example, the input used to create Figures 6.2-6.13 is shown in Figure 6.16.

6.2.2 Comment ("COMMEN")

Card is ignored.

6.2.3 Compress ("COMPRE")

Causes elimination of redundant surface cells.

6.2.4 Conductor Index ("CONDUC")

Causes subsequently defined surfaces to overlay the conductor whose index appears in column 15. The maximum conductor index is 7. The minimum and default is 1.

6.2.5 Deletion ("DELETE")

Causes the volume cell entered in columns 11-25 of card (relative to current offset) [Format (3I5)] to be declared empty and all associated surface cells deleted.

Table 6.1. Literals Recognized by Subroutine INPUT

Commands

Literal[a]	Data	Data Format[b]
COMMENT	(none)	
COMPRESS	(none)	
CONDUCTOR	ICON	(I5)
DELETE	IJK	(3I5)
ENDOBJ	(none)	
ENDSAT	(none)	
MESH SIZE	XMESH	(F10.0)
OFFSET	IOFF	(3I5)

Objects

Literal[a]	Subroutine Called
FIL111	FIL111
OCTAGON	OCTGON
QSPHERE	QSPHER
RECTANGULAR PARALLELEPIPED	RECTAN
TETRAHEDRON	TETRAH
WEDGE	WEDGE

---

[a] Only first six characters significant.

[b] Begins in column 11.

```
ALUMINUM
1.        0.001     -1.       13.       0.97      .3        260.      1.3
240.      1.73      1.36      40.       4.E-05    14.       15.       16.
17.       18.       19.       20.       21.       22.       23.       24.
TEFLON
2.000     0.000127      1.E-14    10.   3.        0.3       -1.       0.
  2.2     16.7      1.4       70.       2.E-05    14.       15.       16.
17.       18.       19.       20.       21.       22.       23.       24.
KAPTON
3.500     0.000127      1.E-14    5.    2.1       0.15      -1.       10.
  1.42    9.8       1.4       70.       .00002    14.       5.        16.
17.       18.       19.       20.       21.       22.       2.        24.
MAGNESIUM
1.        0.001     -1.       12.       0.92      .25       -1.       0.
1.74      24.32     1.36      40.       .00002    14.       15.       16.
17.       18.       19.       20.       21.       22.       23.       24.
SIO2
4.000     0.000127      1.E-14    10.   2.4       0.4       250.      .12
  360.    1.63      1.4       70.       .00002    14.       15.       16.
17.       18.       19.       20.       21.       22.       23.       24.
CONDUCTOR     1
OFFSET        2     2     02
MESH SIZE     .0254
RECTANGULAR PARALLELEPIPED
CORNER        0     0     0
DELTAS        2     3     1
SURFACE   +X        ALUMINUM
SURFACE   +Y        ALUMINUM
SURFACE   +Z        ALUMINUM
SURFACE   -X        KAPTON
SURFACE   -Y        KAPTON
SURFACE   -Z        KAPTON
ENDOBJ
CONDUCTOR     2
OFFSET        12    12    28
QSPHERE
CENTER        -3    -2    0
DIAMETER      4
SIDE          2
MATERIAL  TEFLON
ENDOBJ
CONDUCTOR     3
OFFSET        12    4     24
TETRAHEDRON
CORNER        -1    -1    -1
FACE      TEFLON        1     1     1
LENGTH        2
SURFACE   -X        ALUMINUM
SURFACE   -Y        ALUMINUM
SURFACE   -Z        ALUMINUM
ENDOBJ
CONDUCTOR     4
```

Object 1
Rectangular parallepiped

Object 2
Quasi-sphere

Object 3
Tetrahedron

Figure 6.16. Sample OBJDEF input.

```
OFFSET          3   12   22
OCTAGON
AXIS           00   00   -1        00   00    1
WIDTH           3
SIDE            1
SURFACE   -          ALUMINUM
SURFACE   C          5102
ENDOBJ
CONDUCTOR       5
OFFSET          4    6   12
WEDGE
CORNER         -1   -1   -1
FACE       TEFLON         0    1    1
LENGTH          3    2    2
SURFACE   -X         ALUMINUM
SURFACE   -Y         MAGNESIUM
SURFACE   -Z         ALUMINUM
SURFACE   +X         KAPTON
ENDOBJ
CONDUCTOR       6
OFFSET         12   12    2
RECTANGULAR PARALLELEPIPED
CORNER         -1   -1    0
DELTAS          4    4    1
SURFACE   +X         ALUMINUM
SURFACE   +Y         ALUMINUM
SURFACE   +Z         ALUMINUM
SURFACE   -X         ALUMINUM
SURFACE   -Y         ALUMINUM
SURFACE   -Z         ALUMINUM
ENDOBJ
WEDGE
CORNER          3    3    1
FACE       ALUMIN         -1   -1    0
LENGTH          3    3    3
SURFACE   +X         ALUMINUM
SURFACE   +Y         ALUMINUM
SURFACE   -Z         ALUMINUM
SURFACE   +Z         ALUMINUM
ENDOBJ
OFFSET          0    0    0
FILLET
CORNER         12   15    3        15   12    3
FACE       TEFLON         -1   -1    1
ENDOBJ
ENDSAT
```

Object 4
Right octagonal cy

Object 5
Right triangular prism

Object 6a
Rectangular parallelepiped

Object 6b
Right triangular prism

Object 6c
<111> wedge

Figure 6.16. Sample OBJDEF input (continued).

6.2.6 End definition of geometrical component ("ENDOBJ")

Control is returned to subroutine INPUT.

6.2.7 End object definition ("ENDSAT")

Control is returned to subroutine OBJDEF.

6.2.8 Mesh Size ("MESH S")

The mesh spacing (in meters) is taken to be the floating point number entered in columns 11-20. The default is 0.1 m.

6.2.9 Origin Shift ("OFFSET")

Causes subsequent coordinate definitions to be taken relative to the absolute coordinates entered in columns 11-25 of card in Format (3I5). The default offset is the center of the mesh.

6.2.10 <111> Wedge ("FIL111")

The <111> wedge is used for smoothing stepped surfaces. Its use is illustrated in object 6 of Figures 6.2-6.1.

1. READ (11,21) CCODE, IC

   21 FORMAT (A6, 4X, 3I5, 5X, 3I5)

   CCODE must contain the lateral "CORNER".

   IC (dimension (3,2)) contains the end coordinates of the right-angle-corner line. This line must be in a (110) symmetry direction.

2. READ (11,402) CCODE, SMAT, ID

   Identical to description for "WEDGE", except (1) ID must be a (111) direction normal to line IC, and (2) all exposed surfaces will be of material SMAT.

6.2.11 Octagonal Right Cylinder ("OCTAGO") (see Figure 6.17).

1. READ (11,21) CCODE, IC, ID
   21 FORMAT (A6, 4X, 3I5, 5X, 3I5)
   CCODE must contain the literal 'AXIS'. IC and ID are integer arrays containing the lower and upper indexed ends of the cylinder axis which must parallel a coordinate axis. If WIDTH is odd, the fraction one-half will be added in each direction normal to the axis.

2.-3. READ (11,31) CCODE, ITMP
   31 FORMAT (A6, 4X, I5)
   This read statement is executed twice. CCODE takes on the values 'WIDTH' and 'SIDE'. Integer variables of the same names are set to ITMP. It is required that WIDTH $\geq$ 3. If SIDE $\geq$ WIDTH, a value for SIDE will be provided. Otherwise, SIDE and WIDTH must be both even or both odd.

4. READ (11,241) CCODE, ANS, SMAT
   241 FORMAT (A6, 4X, 2A1, 8X, A6)
   This input is similar to that for 'RECTAN' (6.2.13) except (1) only the first character of ANS is significant, the values '+', '-', and 'C' denoting, respectively, octagonal surfaces at the upper and lower ends of the axis and the circumferential surface, and (2) surfaces not explicitly defined are defaulted to the first material defined.

6.2.12 Twenty-six Faceted Object ("QSPHER")

1. READ (11,21) CCODE, CTR
   21 FORMAT (A6, 4X, 3I5)
   CCODE must contain the literal "CENTER".
   CTR contains the coordinates of the Q-sphere center. For an odd diameter Q-sphere the true center will be (1/2, 1/2, 1/2) relative to the specified coordinates.

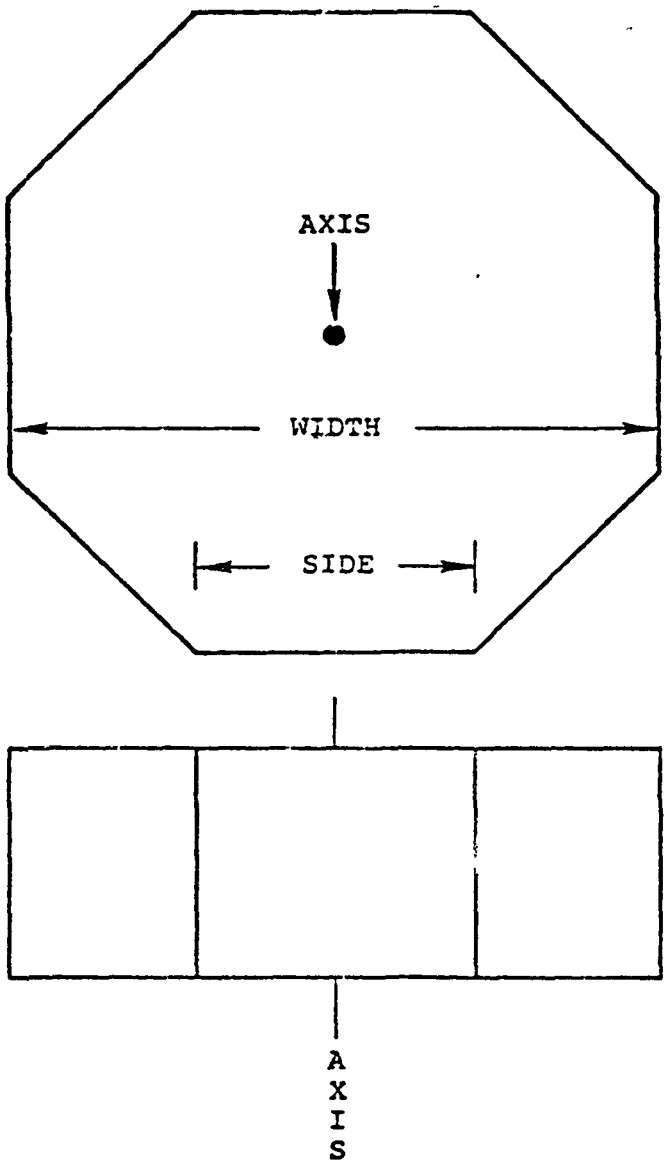

Figure 6.17. Axis, width and side of octagonal right cylinder.

2. READ (11,241) CCODE, SMAT
   241 FORMAT (A6, 4X, A6)
   CCODE may contain the literals "DIAMET", "SIDE", "MATERI", or "ENDOBJ". "DIAMET" and "SIDE" are fully equivalent to "WIDTH" and "SIDE" for "OCTAGO" (q.v.); "SMAT" is decoded with format I5; the defaults are 3 and 1, respectively. "MATERI" indicates the Q-sphere is covered with the material denoted by SMAT.

6.2.13 Rectangular Parallelepiped ("RECTAN")

1. READ (11,21) CCODE, IC
   21 FORMAT (A6, 4X, 3I5)
   CCODE must contain the literal 'CORNER'. IC is an integer array containing the x, y and z coordinates of the lowest-indexed corner.

2. READ (11,21) CCODE, ID
   CCODE must contain the literal 'DELTAS'. ID is an integer array containing the edge lengths parallel to the x, y and z axes.

3. READ (11,241) CCODE, ANS, SMAT
   241 FORMAT (A6, 4X, 2A1, 8X, A6)
   CCODE may be 'SURFAC', 'COMMEN', 'ENDOBJ' or 'ENDSAT'. In the case of a 'SURFAC' card, ANS (an array of length 2) contains the outward surface normal code in the form '+X', '-Y', etc. SMAT contains a material name which must have been previously defined. This read statement continues to be executed until an 'ENDOBJ' or 'ENDSAT' card is encountered, returning control to INPUT.

6.2.14 Tetrahedron ("TETRAH")

1. READ (11,21) CCODE, IC
   21 FORMAT (A6, 4X, 3I5)
   CCODE must contain the literal "CORNER".
   IC contains the coordinate of the right-angle corner.

2. READ (11,402) CCODE, SMAT, ID
   (See description for "WEDGE".)

3. READ (11,21) CCODE, LENGTH
   (Same as for "WEDGE" except only the first value is significant.)

4. READ (11,241) CCODE, ANS, SMAT
   (See description for "RECTAN".)

6.2.15 Right Triangular Right Cylinder ("WEDGE")

1. READ (11,21) CCODE, IC
   21 FORMAT (A6, 4X, 3I5)
   CCODE must contain the literal 'CORNER.' IC is an integer array containing the x, y and z coordinates of the lower-indexed right-angle corner.

2. READ (11,402) CCODE, SMAT, ID
   402 FORMAT (A6, 4X, A6, 4X, 3I5)
   CCODE must contain the literal 'FACE'. SMAT contains a material name which must have been previously defined. ID is an integer array containing the outward surface normal of the slanted face in crystallographic notation.

3. READ (11,21) CCODE, LENGTH
   CCODE must contain the literal 'LENGTH'. LENGTH is an array containing the edge lengths parallel to the coordinate axes.

4. READ (11,241) CCODE, ANS, SMAT
   (See description for 'RECTAN'.)

6.3 PRINTED OUTPUT

Printed output from the object definition section consists of (1) modified input echo, (2) surface cell list, (3) potential coefficients for surface points when determined to be in error, (4) Element Table (LTBL) entries for special cells, Figure 6.15, (5) number of surface points, multiconductor points and special points, (6) potential coefficients for special points when determined to be in error, and (7) tables of material properties. Also printed are statements of the form "CALLING subroutinename" for diagnostic purposes. The output from defining the objects of Figures 6.2-6.13 is shown in Section 6.3.8.

6.3.1 Modified Input Echo

This portion of the output is self-explanatory.

6.3.2 Surface Cell List

A table of surface cells is printed by subroutine DIAGNO, including

1. The cell number (array index).
2. The internal code (octal) for the cell characteristics.
3. The low-index corner (IX,IY,IZ) of the volume cell within which the surface lies, or out of which it points.
4. The outward normal of the surface.
5. The material name corresponding to the surface composition.

6.3.3 Erroneous Potential Coefficients (Surface Points)

Printed when a constant potential is not a local solution. (This output should not occur.)

6.3.4 Element Table (LTBL) Entries for Special Cells

Printed for diagnostic purposes (see Figure 6.15).

6.3.5 Numbers of Surface, Multiconductor and Special Points

This output is self-explanatory. The maximum allowed values are 1024, 100 and 1024, respectively.

6.3.6 Erroneous Potential Coefficients (Special Points)

(See Section 6.3.3).

6.3.7 Material Properties

The input values of the various material properties and their conversion to code units (see Section 6.5).

6.3.8 Printed Output from Figure 6.16

```
ALUMIN              MATERIAL PROPERTIES
            1.00+00     1.0[illegible]-03   -1.00+00    1.30+01    9.70-01    1.00-01    2.60+02    1.30+00    2.40+02    1.73+00
            1.36+00     4.00+01     4.00-05    1.40+01    1.50+01    1.60+01    1.70+01    1.80+01    1.90+01    2.00+01

TEFLON              MATERIAL PROPERTIES
            2.00+00     1.27-04     1.00-14    1.00+01    3.00+00    3.00-01   -1.00+00    0.0[illegible]    2.20+00    1.67+01
            1.40+00     7.00+01     2.00-05    1.40+01    1.50+01    1.60+01    1.70+01    1.80+01    1.90+01    2.00+01

KAPTON              MATERIAL PROPERTIES
            3.50+00     1.27-04     1.00-14    5.00+00    2.10+00    1.50-01   -1.00+00    0.00       1.42+00    9.80+00
            1.40+00     7.00+01     2.00-05    1.40+01    1.50+01    1.60+01    1.70+01    1.80+01    1.90+01    2.00+01

MAGNES              MATERIAL PROPERTIES
            1.00+00     1.00-03    -1.00+00    1.20+01    9.20-01    2.50-01   -1.00+00    0.00       1.74+00    2.43+01
            1.36+00     4.00+01     2.00-05    1.40+01    1.50+01    1.60+01    1.70+01    1.80+01    1.90+01    2.00+01

SIO2                MATERIAL PROPERTIES
            4.00+00     1.27-04     1.00-14    1.00+01    2.40+00    4.00-01    2.50+02    1.20-01    3.60+02    1.63+00
            1.40+00     7.00+01     2.00-05    1.40+01    1.50+01    1.60+01    1.70+01    1.80+01    1.90+01    2.00+01

CONDUC       1

OFFSET       2    2    02

MESH S      .0254

RECTAN    R PARALLELEPIPED
 OBJECT NOW DEFINED.
                                 2<X<  4
                                 2<Y<  5
                                 2<Z<  3

SURFAC    +X        ALUMIN

SURFAC    +Y        ALUMIN

SURFAC    +Z        ALUMIN

SURFAC    -X        KAPTON

SURFAC    -Y        KAPTON

SURFAC    -Z        KAPTON

ENDOBJ

CONDUC       2

OFFSET      12   12   26

WSPHER
```

```
   DEFINING W-SPHERE
         CENTER =    Y  10   28
         DIAMETER =   4      SIDE =    2
         MATERIAL = TEFLON

   OCTAGON DEFINED
         AXIS = 1    X   10   28) TO 1   10   10   28)
         WIDTH =     4            SIDE =     2

   OCTAGON DEFINED
         AXIS = 1    Y    9   28) TO 1    9   11   28)
         WIDTH =     4            SIDE =     2

   OCTAGON DEFINED
         AXIS = 1    Y   10   27) TO 1    9   10   29)
         WIDTH =     4            SIDE =     2

CONDUC        3

OFFSET       12    4   24

TETRAH    N

CORNER       11    3   22

FACE      TEFLON        1    1    1

LENGTH        2

SURFAC    -X        ALUMIN

SURFAC    -Y        ALUMIN

SURFAC    -Z        ALUMIN

ENDOBJ

CONDUC        4

OFFSET        3   12   22

OCTAGO

SURFAC    -         ALUMIN

SURFAC    C         SIO2

ENDOBJ

   OCTAGON DEFINED
         AXIS = 1    3   12   23) TO 1    3   12   23)
         WIDTH =     3            SIDE =     1

CONDUC        5
```

```
OFFSET        4     8    12
WEDGE
CORNER        3     7    11
FACE       TEFLON          0     1     1
LENGTH        3     2     2
SURFAC    -X          ALUMIN
SURFAC    -Y          MAGNES
SURFAC    -Z          ALUMIN
SURFAC    +X          KAPTON
ENDOBJ
CONDUC        6
OFFSET       12    12     2
RECTAN    H PARALLELEPIPED
 OBJECT NOW DEFINED.
                                  11<X< 15
                                  11<Y< 15
                                   2<Z<  3

SURFAC    +X          ALUMIN
SURFAC    +Y          ALUMIN
SURFAC    +Z          ALUMIN
SURFAC    -X          ALUMIN
SURFAC    -Y          ALUMIN
SURFAC    -Z          ALUMIN
ENDOBJ
WEDGE
CORNER       15    15     3
FACE      ALUMIN          -1    -1     0
LENGTH        3     3     3
SURFAC    +X          ALUMIN
```

```
SURFAC    +Y        ALUMIN

SURFAC    -Z        ALUMIN

SURFAC    +Z        ALUMIN

ENDOBJ

OFFSET        0     0     0

FILLII

CORNER       12    15     3        15    12     3

FACE      TEFLON        -1    -1     1
                   DELETING   0019160374 01
                   DELETING   0019160304 01
                   DELETING   0015150374 01
                   DELETING   0016140374 01
                   DELETING   0016140420 01

ENDSAT
CALLING TRNGLS
```

SURFACE CELL LIST

CELL NO.	CODE	CONDUCTOR	IX	IY	IZ	NORMAL	MATERIAL
1	010202020101	1	2	2	2	0 0 1	ALUMIN
2	010202021403	1	2	2	2	0 0 -1	KAPTON
3	010202021403	1	2	2	2	0 -1 0	KAPTON
4	010202026003	1	2	2	2	-1 0 0	KAPTON
5	010203020101	1	2	3	2	0 0 1	ALUMIN
6	010203020303	1	2	3	2	0 0 -1	KAPTON
7	010203026003	1	2	3	2	-1 0 0	KAPTON
8	010204020101	1	2	4	2	0 0 1	ALUMIN
9	010204020303	1	2	4	2	0 0 -1	KAPTON
10	010204020401	1	2	4	2	0 1 0	ALUMIN
11	010204026003	1	2	4	2	-1 0 0	KAPTON
12	010302020101	1	3	2	2	0 0 1	ALUMIN
13	010302020303	1	3	2	2	0 0 -1	KAPTON
14	010302021403	1	3	2	2	0 -1 0	KAPTON
15	010302022001	1	3	2	2	1 0 0	ALUMIN
16	010303020101	1	3	3	2	0 0 1	ALUMIN
17	010303020303	1	3	3	2	0 0 -1	KAPTON
18	010303022001	1	3	3	2	1 0 0	ALUMIN
19	010304020101	1	3	4	2	0 0 1	ALUMIN
20	010304020303	1	3	4	2	0 0 -1	KAPTON
21	010304020401	1	3	4	2	0 1 0	ALUMIN
22	010304022001	1	3	4	2	1 0 0	ALUMIN
23	020710327742	2	7	8	26	-1 -1 -1	TEFLON
24	020710337402	2	7	8	27	-1 -1 0	TEFLON
25	020710347402	2	7	8	28	-1 -1 0	TEFLON
26	020710357542	2	7	8	29	-1 -1 1	TEFLON
27	020711326302	2	7	9	26	-1 0 -1	TEFLON
28	020711336002	2	7	9	27	-1 0 0	TEFLON
29	020711346002	2	7	9	28	-1 0 0	TEFLON
30	020711356102	2	7	9	29	-1 0 1	TEFLON
31	020712326302	2	7	10	26	-1 0 -1	TEFLON
32	020712336002	2	7	10	27	-1 0 0	TEFLON
33	020712346002	2	7	10	28	-1 0 0	TEFLON
34	020712356102	2	7	10	29	-1 0 1	TEFLON
35	020713326742	2	7	11	26	-1 1 -1	TEFLON
36	020713336402	2	7	11	27	-1 1 0	TEFLON
37	020713346402	2	7	11	28	-1 1 0	TEFLON
38	020713356542	2	7	11	29	-1 1 1	TEFLON
39	021610327742	2	8	8	26	0 -1 -1	TEFLON
40	021610331402	2	8	8	27	0 -1 0	TEFLON
41	021610341402	2	8	8	28	0 -1 0	TEFLON
42	021610351502	2	8	8	29	0 -1 1	TEFLON
43	021611326302	2	8	9	26	0 0 -1	TEFLON
44	021611350102	2	8	9	29	0 0 1	TEFLON
45	021612326302	2	8	10	26	0 0 -1	TEFLON
46	021612356102	2	8	10	29	0 0 1	TEFLON
47	021613326742	2	8	11	26	0 1 -1	TEFLON
48	021613336402	2	8	11	27	0 1 0	TEFLON
49	021613340402	2	8	11	28	0 1 0	TEFLON
50	021613350502	2	8	11	29	0 1 1	TEFLON

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OF POOR QUALITY

SURFACE CELL LIST

CELL NO.	CODE	CONDUCTOR	IA	IT	IZ	NORMAL	MATERIAL
51	021110321702	2	9	8	26	0 -1 -1	TEFLON
52	021110331902	2	9	8	27	0 -1 0	TEFLON
53	021110341902	2	9	8	28	0 -1 0	TEFLON
54	021110351502	2	9	8	29	0 -1 1	TEFLON
55	021111320302	2	9	9	26	0 0 -1	TEFLON
56	021111350102	2	9	9	29	0 0 1	TEFLON
57	021112320302	2	9	10	26	0 0 -1	TEFLON
58	021112350102	2	9	10	29	0 0 1	TEFLON
59	021113320702	2	9	11	26	0 1 -1	TEFLON
60	021113330902	2	9	11	27	0 1 0	TEFLON
61	021113340902	2	9	11	28	0 1 0	TEFLON
62	021113350502	2	9	11	29	0 1 1	TEFLON
63	021210323742	2	10	8	26	1 -1 -1	TEFLON
64	021210333902	2	10	8	27	1 -1 0	TEFLON
65	021210343902	2	10	8	28	1 -1 0	TEFLON
66	021210353542	2	10	8	29	1 -1 1	TEFLON
67	021211322302	2	10	9	26	1 0 -1	TEFLON
68	021211332002	2	10	9	27	1 0 0	TEFLON
69	021211342002	2	10	9	28	1 0 0	TEFLON
70	021211352102	2	10	9	29	1 0 1	TEFLON
71	021212322302	2	10	10	26	1 0 -1	TEFLON
72	021212332002	2	10	10	27	1 0 0	TEFLON
73	021212342002	2	10	10	28	1 0 0	TEFLON
74	021212352102	2	10	10	29	1 0 1	TEFLON
75	021213322742	2	10	11	26	1 1 -1	TEFLON
76	021213332902	2	10	11	27	1 1 0	TEFLON
77	021213342902	2	10	11	28	1 1 0	TEFLON
78	021213352542	2	10	11	29	1 1 1	TEFLON
79	031303270301	3	11	3	23	0 0 -1	ALUMIN
80	031303271901	3	11	3	23	0 -1 0	ALUMIN
81	031303272502	3	11	3	23	1 1 1	TEFLON
82	031303276001	3	11	3	23	-1 0 0	ALUMIN
83	031303301991	3	11	3	24	0 -1 0	ALUMIN
84	031303302592	3	11	3	24	1 1 1	TEFLON
85	031303306091	3	11	3	24	-1 0 0	ALUMIN
86	031304270391	3	11	4	23	0 0 -1	ALUMIN
87	031304272592	3	11	4	23	1 1 1	TEFLON
88	031304276091	3	11	4	23	-1 0 0	ALUMIN
89	031403270391	3	12	3	23	0 0 -1	ALUMIN
90	031403271991	3	12	3	23	0 -1 0	ALUMIN
91	031403272592	3	12	3	23	1 1 1	TEFLON
92	040213250391	4	2	11	21	0 0 -1	ALUMIN
93	040213257405	4	2	11	21	-1 -1 0	SIO2
94	040213260191	4	2	11	22	0 0 1	ALUMIN
95	040213267405	4	2	11	22	-1 -1 0	SIO2
96	040214250301	4	2	12	21	0 0 -1	ALUMIN
97	040214256005	4	2	12	21	-1 0 0	SIO2
98	040214260101	4	2	12	22	0 0 1	ALUMIN
99	040214266005	4	2	12	22	-1 0 0	SIO2
100	040215250191	4	2	13	21	0 0 -1	ALUMIN

SURFACE CELL LIST

CELL NO.	CODE	CONDUCTOR	IX	IY	IZ	NORMAL			MATERIAL
101	040215256405	4	2	13	21	-1	1	0	SIO2
102	240215260141	4	2	13	22	0	0	1	ALUMIN
103	040215266405	4	2	13	22	-1	1	0	SIO2
104	040313250301	4	3	11	21	0	0	-1	ALUMIN
105	040313251405	4	3	11	21	0	-1	0	SIO2
106	040313260101	4	3	11	22	0	0	1	ALUMIN
107	040313261405	4	3	11	22	0	-1	0	SIO2
108	040314250301	4	3	12	21	0	0	-1	ALUMIN
109	040314260101	4	3	12	22	0	0	1	ALUMIN
110	040315250301	4	3	13	21	0	0	-1	ALUMIN
111	040315250405	4	3	13	21	0	1	0	SIO2
112	040315260101	4	3	13	22	0	0	1	ALUMIN
113	040315260405	4	3	13	22	0	1	0	SIO2
114	140413250341	4	4	11	21	0	0	-1	ALUMIN
115	040413253405	4	4	11	21	1	-1	0	SIO2
116	140413260141	4	4	11	22	0	0	1	ALUMIN
117	040413263405	4	4	11	22	1	-1	0	SIO2
118	040414250301	4	4	12	21	0	0	-1	ALUMIN
119	040414252005	4	4	12	21	1	0	0	SIO2
120	040414260101	4	4	12	22	0	0	1	ALUMIN
121	040414262005	4	4	12	22	1	0	0	SIO2
122	040415250341	4	4	13	21	0	0	-1	ALUMIN
123	040415252405	4	4	13	21	1	1	0	SIO2
124	040415260141	4	4	13	22	0	0	1	ALUMIN
125	040415262405	4	4	13	22	1	1	0	SIO2
126	050307130301	5	3	7	11	0	0	-1	ALUMIN
127	050307131404	5	3	7	11	0	-1	0	MAGNES
128	050307136001	5	3	7	11	-1	0	0	ALUMIN
129	050307140502	5	3	7	12	0	1	1	TEFLON
130	050307141404	5	3	7	12	0	-1	0	MAGNES
131	050307146041	5	3	7	12	-1	0	0	ALUMIN
132	050310130301	5	3	8	11	0	0	-1	ALUMIN
133	050310130502	5	3	8	11	0	1	1	TEFLON
134	050310136041	5	3	8	11	-1	0	0	ALUMIN
135	050407130301	5	4	7	11	0	0	-1	ALUMIN
136	050407131404	5	4	7	11	0	-1	0	MAGNES
137	050407140502	5	4	7	12	0	1	1	TEFLON
138	050407141404	5	4	7	12	0	-1	0	MAGNES
139	050410130301	5	4	8	11	0	0	-1	ALUMIN
140	050410130502	5	4	8	11	0	1	1	TEFLON
141	050507130301	5	5	7	11	0	0	-1	ALUMIN
142	050507131404	5	5	7	11	0	-1	0	MAGNES
143	050507132003	5	5	7	11	1	0	0	KAPTON
144	050507140502	5	5	7	12	0	1	1	TEFLON
145	050507141404	5	5	7	12	0	-1	0	MAGNES
146	050507142043	5	5	7	12	1	0	0	KAPTON
147	050510130301	5	5	8	11	0	0	-1	ALUMIN
148	050510130502	5	5	8	11	0	1	1	TEFLON
149	050510132043	5	5	8	11	1	0	0	KAPTON
150	061313020101	6	11	11	2	0	0	1	ALUMIN

SURFACE CELL LIST

CELL NO.	CODE	CONDUCTOR	IA	IT	IZ	NORMAL	MATERIAL
151	061312023301	6	11	11	2	0 0 -1	ALUMIN
152	061312021401	6	11	11	2	0 -1 0	ALUMIN
153	061312026001	6	11	11	2	-1 0 0	ALUMIN
154	061314020101	6	11	12	2	0 0 1	ALUMIN
155	061314020301	6	11	12	2	0 0 -1	ALUMIN
156	061314026001	6	11	12	2	-1 0 0	ALUMIN
157	061315020101	6	11	13	2	0 0 1	ALUMIN
158	061315020301	6	11	13	2	0 0 -1	ALUMIN
159	061315026001	6	11	13	2	-1 0 0	ALUMIN
160	061317020141	6	11	14	2	0 0 1	ALUMIN
161	061316020301	6	11	14	2	0 0 -1	ALUMIN
162	061316021401	6	11	14	2	0 1 0	ALUMIN
163	061316026001	6	11	14	2	-1 0 0	ALUMIN
164	061316030442	6	11	14	3	0 1 0	TEFLON
165	061316037542	6	11	14	3	-1 -1 1	TEFLON
166	061413020101	6	12	11	2	0 0 1	ALUMIN
167	061413020301	6	12	11	2	0 0 -1	ALUMIN
168	061413021401	6	12	11	2	0 -1 0	ALUMIN
169	061414020101	6	12	12	2	0 0 1	ALUMIN
170	061414020301	6	12	12	2	0 0 -1	ALUMIN
171	061415020101	6	12	13	2	0 0 1	ALUMIN
172	061415020301	6	12	13	2	0 0 -1	ALUMIN
173	061415037542	6	12	13	3	-1 -1 1	TEFLON
174	061416020301	6	12	14	2	0 0 -1	ALUMIN
175	061416021401	6	12	14	2	0 1 0	ALUMIN
176	061416030402	6	12	14	3	0 1 0	TEFLON
177	061416037502	6	12	14	3	-1 -1 1	TEFLON
178	061416040401	6	12	14	4	0 1 0	ALUMIN
179	061416047401	6	12	14	4	-1 -1 0	ALUMIN
180	061416050141	6	12	14	5	0 0 1	ALUMIN
181	061416050401	6	12	14	5	0 1 0	ALUMIN
182	061416057401	6	12	14	5	-1 -1 0	ALUMIN
183	061513020101	6	13	11	2	0 0 1	ALUMIN
184	061513020301	6	13	11	2	0 0 -1	ALUMIN
185	061513021401	6	13	11	2	0 -1 0	ALUMIN
186	061514020141	6	13	12	2	0 0 1	ALUMIN
187	061514020301	6	13	12	2	0 0 -1	ALUMIN
188	061514037542	6	13	12	3	-1 -1 1	TEFLON
189	061515020301	6	13	13	2	0 0 -1	ALUMIN
190	061515037502	6	13	13	3	-1 -1 1	TEFLON
191	061515047401	6	13	13	4	-1 -1 0	ALUMIN
192	061515050141	6	13	13	5	0 0 1	ALUMIN
193	061515057401	6	13	13	5	-1 -1 0	ALUMIN
194	061516020301	6	13	14	2	0 0 -1	ALUMIN
195	061516020401	6	13	14	2	0 1 0	ALUMIN
196	061516030401	6	13	14	3	0 1 0	ALUMIN
197	061516040401	6	13	14	4	0 1 0	ALUMIN
198	061516050101	6	13	14	5	0 0 1	ALUMIN
199	061516050401	6	13	14	5	0 1 0	ALUMIN
200	061613020141	6	14	11	2	0 0 1	ALUMIN

SURFACE CELL LIST

CELL NO.	CODE	CONDUCTOR	IX	IY	IZ	NORMAL	MATERIAL
201	061613020301	6	14	11	2	0 0 -1	ALUMIN
202	061613021401	6	14	11	2	0 -1 0	ALUMIN
203	061613022001	6	14	11	2	1 0 0	ALUMIN
204	261613032042	6	14	11	3	1 0 0	TEFLON
205	061613037542	6	14	11	3	-1 -1 1	TEFLON
206	061614020301	6	14	12	2	0 0 -1	ALUMIN
207	061614022001	6	14	12	2	1 0 0	ALUMIN
208	061614032002	6	14	12	3	1 0 0	TEFLON
209	061614037502	6	14	12	3	-1 -1 1	TEFLON
210	061614042001	6	14	12	4	1 0 0	ALUMIN
211	061614047401	6	14	12	4	-1 -1 0	ALUMIN
212	061614050141	6	14	12	5	0 0 1	ALUMIN
213	061614052001	6	14	12	5	1 0 0	ALUMIN
214	061614057401	6	14	12	5	-1 -1 0	ALUMIN
215	061615020301	6	14	13	2	0 0 -1	ALUMIN
216	061615022001	6	14	13	2	1 0 0	ALUMIN
217	061615032001	6	14	13	3	1 0 0	ALUMIN
218	061615042001	6	14	13	4	1 0 0	ALUMIN
219	061615050101	6	14	13	5	0 0 1	ALUMIN
220	061615052001	6	14	13	5	1 0 0	ALUMIN
221	061616020301	6	14	14	2	0 0 -1	ALUMIN
222	061616020401	6	14	14	2	0 1 0	ALUMIN
223	061616022001	6	14	14	2	1 0 0	ALUMIN
224	061616030401	6	14	14	3	0 1 0	ALUMIN
225	061616032001	6	14	14	3	1 0 0	ALUMIN
226	061616040401	6	14	14	4	0 1 0	ALUMIN
227	061616042001	6	14	14	4	1 0 0	ALUMIN
228	061616050101	6	14	14	5	0 0 1	ALUMIN
229	061616050401	6	14	14	5	0 1 0	ALUMIN
230	061616052001	6	14	14	5	1 0 0	ALUMIN

PREPROCESSING OF MATERIAL PROPERTIES

MATERIAL 1: ALUMIN

	PROPERTY	INPUT VALUE	CODE VALUE
1	DIELECTRIC CONSTANT	1.00+00 (NONE)	1.00+00 (NONE)
2	THICKNESS	1.00-03 METERS	3.94-02 MESH
3	CONDUCTIVITY	-1.00+00 MHO/M	-1.00+00 MHO/M
4	ATOMIC NUMBER	1.30+01 (NONE)	1.30+01 (NONE)
5	DELTA MAX >COEFF	9.70-01 (NONE)	7.21+00 (NONE)
6	E-MAX >DEPTH**-1	3.00-01 KEV	1.73-02 ANG-01
7	RANGE	2.60+02 ANG.	3.38+02 ANG.
8	EXPONENT > RANGE	1.30+00 (NONE)	9.15+02 ANG.
9	RANGE > EXPONENT	2.90+02 ANG.	1.30+00 (NONE)
10	EXPONENT	1.73+00 (NONE)	1.73+00 (NONE)
11	YIELD FOR 1KEV PHOTONS	1.30+00 (NONE)	1.30+00 (NONE)
12	MAX DE/DX FOR PHOTONS	4.00+01 KEV	4.00+01 KEV
13	PHOTOCURRENT	4.00-05 A/M**2	4.00-05 A/M**2
14		1.40+01	1.40+01
15		1.50+01	1.50+01
16		1.60+01	1.60+01
17		1.70+01	1.70+01
18		1.80+01	1.80+01
19		1.90+01	1.90+01
20		2.00+01	2.00+01

MATERIAL 2: TEFLON

	PROPERTY	INPUT VALUE	CODE VALUE
1	DIELECTRIC CONSTANT	2.00+00 (NONE)	2.00+00 (NONE)
2	THICKNESS	1.27-04 METERS	5.00-03 MESH
3	CONDUCTIVITY	1.00-14 MHO/M	1.00-14 MHO/M
4	ATOMIC NUMBER	1.00+01 (NONE)	1.00+01 (NONE)
5	DELTA MAX >COEFF	3.00+00 (NONE)	1.96+01 (NONE)
6	E-MAX >DEPTH**-1	3.00-01 KEV	2.99-02 ANG-01
7	RANGE	-1.00+00 ANG.	4.58+02 ANG.
8	EXPONENT > RANGE	0.00 (NONE)	0.00 ANG.
9	RANGE > EXPONENT	2.20+00 ANG.	1.69+00 (NONE)
10	EXPONENT	1.67+01 (NONE)	1.00+00 (NONE)
11	YIELD FOR 1KEV PHOTONS	1.40+00 (NONE)	1.40+00 (NONE)
12	MAX DE/DX FOR PHOTONS	7.00+01 KEV	7.00+01 KEV
13	PHOTOCURRENT	2.00-05 A/M**2	2.00-05 A/M**2
14		1.40+01	1.40+01
15		1.50+01	1.50+01
16		1.60+01	1.60+01
17		1.70+01	1.70+01
18		1.80+01	1.80+01
19		1.90+01	1.90+01
20		2.00+01	2.00+01

MATERIAL 3: KAPTON

	PROPERTY	INPUT VALUE	CODE VALUE
1	DIELECTRIC CONSTANT	3.50+00 (NONE)	3.50+00 (NONE)

2	THICKNESS	1.27-04	METERS	5.00-03	MESH
3	CONDUCTIVITY	1.00-14	MHO/M	1.00-14	MHO/M
4	ATOMIC NUMBER	5.00+00	(NONE)	5.00+00	(NONE)
5	DELTA MAX >COEFF	2.10+00	(NONE)	3.05+01	(NONE)
6	E-MAX >DEPTH**-1	1.50-01	KEV	4.62-02	ANG-01
7	RANGE	-1.00+00	ANG.	7.73+02	ANG.
8	EXPONENT > RANGE	0.00	(NONE)	0.00	ANG.
9	RANGE > EXPONENT	1.42+00	ANG.	1.51+00	(NONE)
10	EXPONENT	9.80+00	(NONE)	1.00+00	(NONE)
11	YIELD FOR 1KEV PROTONS	1.40+00	(NONE)	1.40+00	(NONE)
12	MAX DE/DX FOR PROTONS	7.00+01	KEV	7.00+01	KEV
13	PHOTOCURRENT	2.00-05	A/M**2	2.00-05	A/M**2
14		1.40+01		1.40+01	
15		1.50+01		1.50+01	
16		1.60+01		1.60+01	
17		1.70+01		1.70+01	
18		1.80+01		1.80+01	
19		1.90+01		1.90+01	
20		2.00+01		2.00+01	

MATERIAL 4: MAGNES

	PROPERTY	INPUT VALUE		CODE VALUE	
1	DIELECTRIC CONSTANT	1.00+00	(NONE)	1.00+00	(NONE)
2	THICKNESS	1.00-03	METERS	3.94-02	MESH
3	CONDUCTIVITY	-1.00+00	MHO/M	-1.00+00	MHO/M
4	ATOMIC NUMBER	1.20+01	(NONE)	1.20+01	(NONE)
5	DELTA MAX >COEFF	9.20-01	(NONE)	7.02+00	(NONE)
6	E-MAX >DEPTH**-1	2.50-01	KEV	2.79-02	ANG-01
7	RANGE	-1.00+00	ANG.	6.97+02	ANG.
8	EXPONENT > RANGE	0.00	(NONE)	0.00	ANG.
9	RANGE > EXPONENT	1.74+00	ANG.	1.75+00	(NONE)
10	EXPONENT	2.43+01	(NONE)	1.00+00	(NONE)
11	YIELD FOR 1KEV PROTONS	1.36+00	(NONE)	1.36+00	(NONE)
12	MAX DE/DX FOR PROTONS	4.00+01	KEV	4.00+01	KEV
13	PHOTOCURRENT	2.00-05	A/M**2	2.00-05	A/M**2
14		1.40+01		1.40+01	
15		1.50+01		1.50+01	
16		1.60+01		1.60+01	
17		1.70+01		1.70+01	
18		1.80+01		1.80+01	
19		1.90+01		1.90+01	
20		2.00+01		2.00+01	

MATERIAL 5: SIO2

	PROPERTY	INPUT VALUE		CODE VALUE	
1	DIELECTRIC CONSTANT	4.00+00	(NONE)	4.00+00	(NONE)
2	THICKNESS	1.27-04	METERS	5.00-03	MESH
3	CONDUCTIVITY	1.00-14	MHO/M	1.00-14	MHO/M
4	ATOMIC NUMBER	1.00+01	(NONE)	1.00+01	(NONE)
5	DELTA MAX >COEFF	2.40+00	(NONE)	1.54+01	(NONE)
6	E-MAX >DEPTH**-1	4.00-01	KEV	1.59-02	ANG-01
7	RANGE	2.50+02	ANG.	3.00+01	ANG.

8	EXPONENT > RANGE	1.20-01 (NONE)	5.87+02 ANG.
9	RANGE > EXPONENT	3.60+02 ANG.	1.20-01 (NONE)
10	EXPONENT	1.63+00 (NONE)	1.63+00 (NONE)
11	YIELD FOR 1KEV PROTONS	.40+00 (NONE)	1.40+00 (NONE)
12	MAX DE/DX FOR PROTONS	7.00+01 KEV	7.00+01 KEV
13	PHOTOCURRENT	2.00-05 A/M**2	2.00-05 A/M**2
14		1.40+01	1.40+01
15		1.50+01	1.50+01
16		1.60+01	1.60+01
17		1.70+01	1.70+01
18		1.80+01	1.80+01
19		1.90+01	1.90+01
20		2.00+01	2.00+01

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CALLING SREPIS
 CALLING SPECEL
CALLING SPEWGT
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ELEMENT TABLE

I	J	K	FORM
2	7	12	0000020235C2
2	8	11	0000020235C2
2	11	20	0000[illegible]012702
2	11	21	0000200563C1
2	11	22	0000200563C1
2	11	23	0000[illegible]012362
2	13	20	0000[illegible]052702
2	13	21	0000[illegible]052361
2	13	22	0000[illegible]052361
2	13	23	0000[illegible]052362
3	7	12	0000060231C1
3	8	11	0000060231C1
4	7	12	0000060231C1
4	8	11	0000060231C1
4	11	20	0000[illegible]052702
4	11	21	0000000163C1
4	11	22	0000000163C1
4	11	23	0000[illegible]052362
4	13	20	0000[illegible]012702
4	13	21	0000[illegible]012361
4	13	22	0000[illegible]012361
4	13	23	0000[illegible]012362
5	7	12	0000[illegible]023101
5	8	11	0000[illegible]023101
6	7	12	0000[illegible]023102
6	8	11	0000[illegible]023102
7	8	26	0000[illegible]056704
7	8	27	0000[illegible]056361
7	8	28	0000[illegible]056361
7	8	29	0000[illegible]056364
7	9	26	0000[illegible]075201
7	9	29	0000[illegible]035201
7	10	26	0000[illegible]075201
7	10	29	0000[illegible]035201
7	11	26	0000[illegible]052704
7	11	27	0000[illegible]052361
7	11	28	0000[illegible]052361
7	11	29	0000[illegible]052364
8	8	26	0000[illegible]067101
8	8	29	0000[illegible]063101
8	11	26	0000[illegible]027101
8	11	29	0000[illegible]023101
9	8	26	0000[illegible]067101
9	8	29	0000[illegible]063101
9	11	26	0000[illegible]027101
9	11	29	0000[illegible]023101
10	3	24	0000[illegible]023502
10	4	23	0000[illegible]023502
10	8	26	0000[illegible]016704
10	8	27	0000[illegible]016361
10	8	28	0000[illegible]016361

ORIGINAL PAGE IS
OF POOR QUALITY

```
 10    8    29      000100061309
 10    9    26      000100071201
 10    9    29      000100031201
 10   10    26      000100071201
 10   10    29      000100031201
 10   11    26      000100012709
 10   11    27      000100012301
 10   11    28      000100012301
 10   11    29      000100012309
 11    2    29      000020203P6G2
 11    3    23      000200012303
 11    3    29      000200012309
 11    4    22      000202012702
 11    4    23      000200012309
 11   14     3      000020056309
 11   15     3      000020071202
 12    2    23      000020031702
 12    3    22      000020017702
 12    3    23      000200012309
 12   13     3      000200056309
 12   14     3      000200056303
 12   14     4      000200056301
 12   14     5      000200056301
 12   14     6      000020012302
 13   12     3      000200056309
 13   13     3      000200056303
 13   13     4      000200056301
 13   13     5      000200056301
 13   13     6      000020012302
 14   11     3      000200056309
 14   12     3      000200056303
 14   12     4      000200056301
 14   12     5      000200056301
 14   12     6      000020012302
 15   11     3      000020063102
CALLING SPCPTS
CALLING SPCWGT
```

```
        219 SURFACE POINTS, INCLUDING      0 MULTICONDUCTOR POINTS.

        174 SPECIAL POINTS


        226 VOLUME CELLS NUMBERED BY NUMLTB.

 FINAL NAI =    103

 FINAL NAI =    105

 FINAL NAI =    117


@PMD,GED

PMD  T26-07/27- 17:23:37
SYS$*HLIB$. LEVEL 570-1
```

6.4 OUTPUT TO FILES IOBPLT, IOBJ

6.4.1 File IPLOT [=ABS(IOBPLT)]

IPLOT is a FORTRAN unformatted file. The contents of successive records are listed below. Quantities in parentheses are dimensions. See glossary for definitions.

1. XMESH
2. NMAT, MCODE(15), MATPR(20,15)
3. NSURF, JSURF(1024)
4. NBLK, NPBLK(64), IPER(3,32,64), IFAC(80)
5. NSPTS, NPTS
6. SWPCND(7)
7. LTBL(17,17,33)

6.4.2 File IOBJ

IOBJ is an NTRAN file intended for use by routine OBJSPC. It contains

1. Potential coefficients linking multiconductor points to conductors (PMCND)
2. List of surface points
3. Potential coefficients linking surface points to conductors
4. Space potential coefficients for surface points
5. List of special points
6. Space potential coefficients for special points

6.5 MATERIAL PROPERTIES

6.5.1 Definition

The present version of NASCAP makes use of thirteen material properties; storage is provided for twenty. The twenty values are read on three cards following the material name using FORMAT (F10.0). The input values are converted to code values by subroutine MATPRO and its subsidiary routines.

Property 1: Relative dielectric constant (dimensionless).

Property 2: Thickness of dielectric film or vacuum gap (meters).

Property 3: Electrical conductivity (mho/m). The value -1. indicates a vacuum gap over a conducting surface.

Property 4: Atomic number (dimensionless).

Property 5: Maximum secondary electron yield for electron impact at normal incidence (dimensionless).

Property 6: Primary electron energy to produce maximum yield at normal incidence (keV).

Properties 7-10: Range for incident electrons. Either:

$$\text{Range} = P_7 E^{P_8} + P_9 E^{P_{10}}$$

where the range is in angstroms and for the energy in keV,

or

P_7 = -1. to indicate use of Feldman's[1] empirical range formula

P_9 = density (g/cm^3)

P_{10} = mean atomic weight (dimensionless)

Property 11: Secondary electron yield for normally incident 1 keV protons.

Property 12: Proton energy to produce maximum secondary electron yield (keV).

Property 13: Photoelectron yield for normally incident sunlight (A/m^2).

6.5.2 Sample Values

There is a great deal of uncertainty in all property values concerned with particle range, low energy electron emission or conductivity of insulators. With that warning, we present below the input values we have tentatively adopted for clean aluminum, clean magnesium, teflon, kapton and SiO_2.

Aluminum

Property	Value	Comment
1	1.0	Vacuum gap
2	0.001	$\sim 10^{-2}$ mesh units
3	-1.	Conductor
4	13.	
5	0.97	See Reference 2-4
6	0.3 keV	
7	260 A	See Reference 5
8	1.3	
9	240 A	
10	1.73	
11	1.36	
12	40 keV	
13	4.0×10^{-5} A/m^2	See Reference 6

Magnesium

Property	Value	Comment
1	1.0	Vacuum gap
2	0.001	$\sim 10^{-2}$ mesh units
3	-1.	Conductor
4	12.	
5	0.92	See Reference 2-4
6	0.25 keV	
7	-1.	Feldman's formulation, Reference 1
8	--	
9	1.74	Density, gm/cm^3
10	24.3	Atomic weight
11	1.36	
12	40. keV	
13	2.0×10^{-5} A/m^2	

Teflon

Property	Value	Comment
1	2.0	
2	1.27×10^{-4}	5 mil
3	1.0×10^{-14} mho/m	
4	10.	
5	3.0	Reference 7
6	0.3 keV	
7	-1.	Feldman's formulation, Reference 1
8	--	
9	2.00	Density, gm/cm^3
10	16.7	Atomic weight
11	1.40	
12	70 keV	
13	2.0×10^{-5} A/m^2	

Kapton

Property	Value	Comment
1	3.5	
2	1.27×10^{-4}	5 mil
3	1.0×10^{-14} mho/m	
4	5.0	
5	2.1	Reference 7
6	0.150 keV	
7	-1.	Feldman's formulation, Reference 1
8	--	
9	1.42	Density, gm/cm^{-3}
10	9.8	Atomic weight
11	1.40	
12	70. keV	
13	2.0×10^{-5} A/m^2	

SiO_2

Property	Value	Comment
1	4.0	
2	1.27×10^{-4}	5 mil
3	1.0×10^{-14} mho/m	
4	10.	
5	2.4	Reference 2-4
6	0.4 keV	
7	250 A	Reference 8
8	0.12	
9	360 A	
10	1.63	
11	1.40	
12	70.0 keV	
13	2.0×10^{-5} A/m^2	

6.6 CODE DETAILS

The main routine for the object definition section of NASCAP is the subroutine OBJDEF. A flowchart of this routine is shown in Figure 6.18. The three main functions are: (1) determine the geometrical configuration and surface cell list from user input, (2) perform preprocessing of the material properties, and (3) determine the surface points, special points and their potential coefficients. The subroutine writeups which follow are divided into (1) general and miscellaneous routines, (2) geometrical object routines, (3) material routines, and (4) point and potential coefficient routines.

6.6.1 General and Miscellaneous Routines

CMPRSS

Purpose: Eliminate superfluous or redundant surface cells.

Calling Sequence: SUBROUTINE CMPRSS (LTBL,NX,NY,NZ)

Called By: INPUT, OBJDEF, QSPHER

CONDUC

Purpose: Places conductor indices in surface cell array.

Calling Sequence: SUBROUTINE CONDUC (NCON)

Called By: INPUT

DIAGNO

Purpose: Prints list of surface cells.

Calling Sequence: SUBROUTINE DIAGNO

Called By: OBJDEF

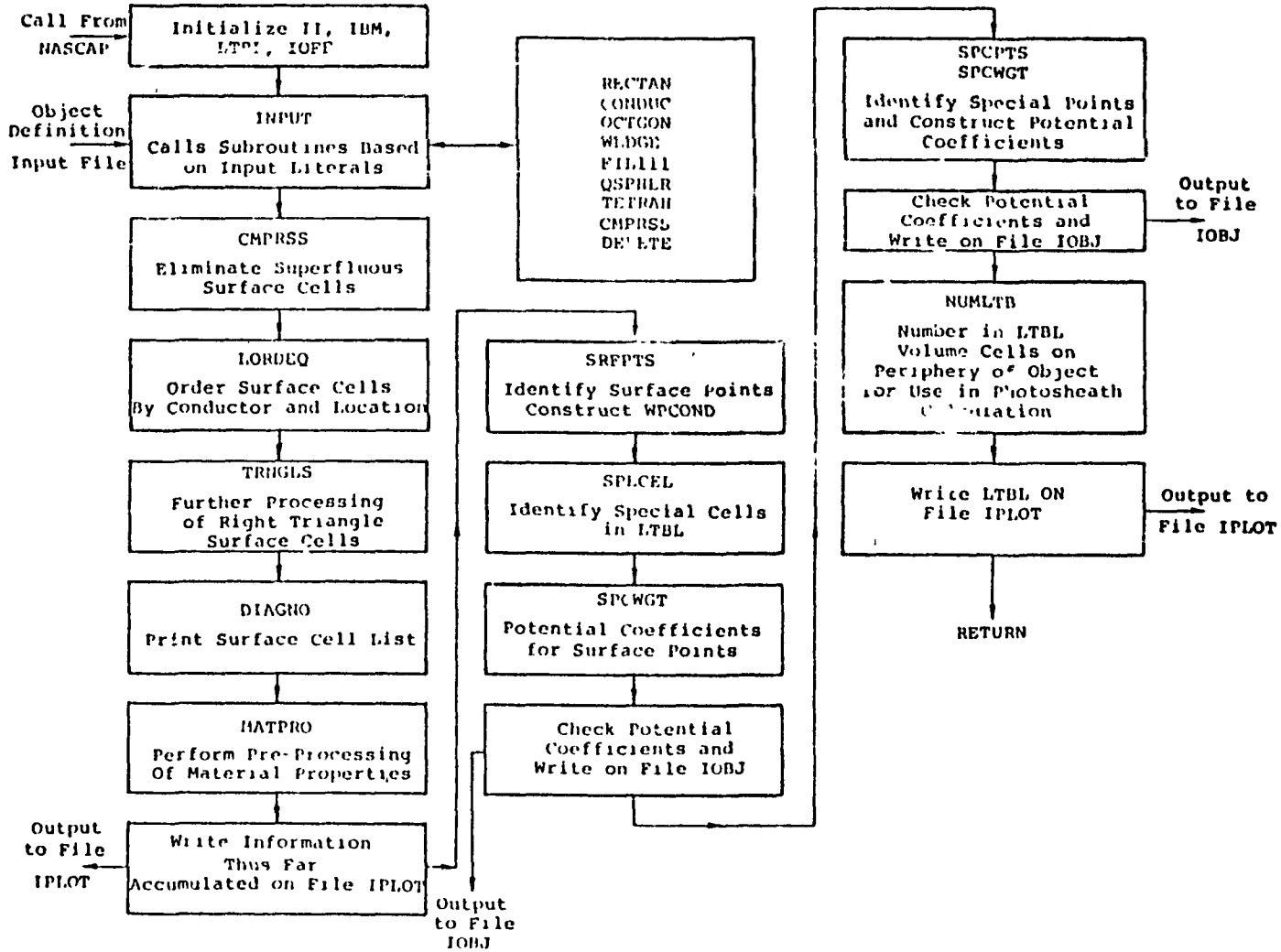


Figure 6.18. OBJDEF flow chart.

DELETE

Purpose: Deletes a volume cell and all associated surface cells.

Calling Sequence: SUBROUTINE DELETE (IOFF,LTBL,NX,NY,NZ,IJK)

Called By: INPUT, FIL111

INPUT

Purpose: Reads keywords from ISAT input file and calls object definition routines.

Calling Sequence: SUBROUTINE INPUT (IOFF,LTBL,NX,NY,NZ,ISAT)

Called By: OBJDEF

LORDEQ

Purpose: Identical to LORDER (q.v.).

Calling Sequence: SUBROUTINE LORDEQ (LIST,W)

Called By: OBJDEF

NUMLTB

Purpose: Number volume cells (LTBL) adjacent to object for purpose of calculating low-energy electron flux.

Calling Sequence: SUBROUTINE NUMLTB (LTBL,NX,NY,NZ)

Called By: OBJDEF

OBJDEF

Purpose: Primary routine for object definition section of NASCAP code. (See Figure 6.18.)

Calling Sequence: SUBROUTINE OBJDEF (NX,NY,NZ,NC)

Called By: NASCAP

SETMC

Purpose: Establishes the Ith surface point as the Jth multi-conductor point.

Calling Sequence: SUBROUTINE SETMC (I,J)

Called By: SRFPTS

6.6.2 Geometrical Object Routines

CFLICT

Purpose: Determines if a right-triangular surface cell is valid, superfluous or illegal.

Calling Sequence: SUBROUTINE CFLICT (N100,NORM,IB5,IRET)

Called By: Several geometrical object routines and CMPRSS.

CUBE34

Purpose: Defines a truncated-cube volume cell.

Calling Sequence: SUBROUTINE CUBE34 (IOFF,LTBL,NX,NY,NZ,STUFF)

Called By: FIL111

FIL111

Purpose: Defines a wedge with (111)-type surface normal.

Calling Sequence: SUBROUTINE FIL111 (IOFF,LTBL,NX,NY,NZ,ISAT)

Called By: INPUT

NIOOBJ

Purpose: Defines a rectangular parallelepiped with parameters passed in array JSTUFF.

Calling Sequence: SUBROUTINE NIOOBJ (LTBL,NX,NY,NZ,JSTUFF)

Called By: NIOOCT

NIOOCT

Purpose: Defines an octagonal right cylinder as two RECTAN'S and four WEDGE's from parameters passed in array JSTUFF.

Calling Sequence: SUBROUTINE NIOOCT (IOFF,LTBL,NX,NY,NZ,JSTUFF)

Called By: OCTGON, QSPHER

NIOTET

Purpose: Defines a tetrahedron from parameters passed in array JSTUFF.

Calling Sequence: SUBROUTINE NIOTET (IOFF,LTBL,NX,NY,NZ,JSTUFF)

Called By: QSPHER

NIOWGE

Purpose: Defines a right triangular cylinder (WEDGE) from parameters passed in array JSTUFF.

Calling Sequence: SUBROUTINE NIOWGE (LTBL,NX,NY,NZ,JSTUFF)

Called By: OCTGON, QSPHER

OCTGON

Purpose: Defines an octagonal right cylinder from input data as two rectangular parallelepipeds and four wedges.

Calling Sequence: SUBROUTINE OCTGON (IOFF,LTBL,NX,NY,NZ,ISAT)

Called By: INPUT

QSPHER

Purpose: Defines a quasi-sphere from input data.

Calling Sequence: SUBROUTINE QSPHER (IOFF,LTBL,NX,NY,NZ,ISAT)

Called By: INPUT

RECTAN

Purpose: Defines a rectangular parallelepiped from input data.

Calling Sequence: SUBROUTINE RECTAN (IOFF,LTBL,NX,NY,NZ,ISAT)

Called By: INPUT

TETRAH

Purpose: Defines a tetrahedron from input data.

Calling Sequence: SUBROUTINE TETRAH (IOFF,LTBL,NX,NY,NZ,ISAT)

Called By: INPUT

TRNGLS

Purpose: Performs further processing of right-triangle surface cells, including determination of right-angle corner location and elimination of redundant cells.

Calling Sequence: SUBROUTINE TRNGLS (LTBL,NX,NY,NZ)

Called By: OBJDEF

WEDGE

Purpose: Defines a right triangular cylinder (WEDGE) from input data.

Calling Sequence: SUBROUTINE WEDGE (IOFF,LTBL,NX,NY,NZ,ISAT)

Called By: INPUT

6.6.3 Materials Routines

ELSEC1

Purpose: Identical to ELSEC (q.v.)

Calling Sequence: SUBROUTINE ELSEC1 (YIELD,E,THETA,IOPT)

Called By: INEIMP

INEIMP

Purpose: Preprocesses material parameters associated with electron secondary emission.

Calling Sequence: SUBROUTINE INEIMP (MPRM)

Called By: MATPRO

MATPRO

Purpose: Preprocessing of material property parameters.

Calling Sequence: SUBROUTINE MATPRO

Called By: OBJDEF

QEQN

Purpose: Routine used in preprocessing of electron-produced secondary material parameters.

Calling Sequence: FUNCTION QEQN (Z,K,Q)

Called By: INEIMP through ZSYSTM

QEQN2

Purpose: Routine used in preprocessing of electron-produced secondary material parameters.

Calling Sequence: FUNCTION QEQN2 (Z,K,Q)

Called By: INEIMP through ZSYSTM

ZSYSTM

Purpose: Modified version of IMSL routine to solve a system of nonlinear equations.

Calling Sequence: SUBROUTINE ZSYSTM (F,EPS,NSIG,N,X,ITMAX,
WA,PAR,IER)

Called By: INEIMP

6.6.4 Point and Potential Coefficient Routines

IBIT

Purpose: Extracts N bits from word I, with bit NO the rightmost bit. (The rightmost bit of a word is bit 0.) Substitute for FLD functions for machine independence.

Calling Sequence: FUNCTION IBIT (I,NO,N)

Called By: PERMU, SPECEL, others

PERMU

Purpose: Generates permutation vector from LTBL entry. (See Figure 6.15.)

Calling Sequence: SUBROUTINE PERMU (IPMU,ECODE)
IPMU(8) - Permutation vector for cube vertices
ECODE - element table (LTBL) entry

Called By: SPCWGT

SPECEL

Purpose: Identifies special cells and puts LTBL in its final form except for numbering by NUMLTB. (See Figures 6.19-6.24.)

Calling Sequence: SUBROUTINE SPECEL (LTBL,NX,NY,NZ)

Called By: OBJDEF

SPCPTS

Purpose: Forms list of special points.

Calling Sequence: SUBROUTINE SPCPTS (LTBL,NX,NY,NZ)

Called By: OBJDEF

(Format)

Description

Standard Orientation

Potential Function = $\sum_i N^i \phi_i$

Weight Matrix, W_{ij}: $\int d\Omega |\nabla\phi|^2 = \sum_{ij} W_{ij}\phi_i\phi_j$

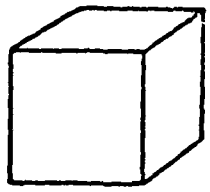
Point Index	Cube Corner
1	0 0 0
2	1 0 0
3	0 1 0
4	1 1 0
5	0 0 1
6	1 0 1
7	0 1 1
8	1 1 1

Figure 6.19. Format and definition of point indices for Figures 6.20-6.24.

Standard Cell 0

Empty trilinear cube

Orientation: Arbitrary



Potential Function:

i	N^i
1	$(1-x)(1-y)(1-z)$
2	$(1-z)(1-y)x$
3	$(1-x)y(1-z)$
4	$(1-z)yx$
5	$z(1-y)(1-x)$
6	$x(1-y)(z$
7	$zy(1-x)$
8	xyz

W_{ij}

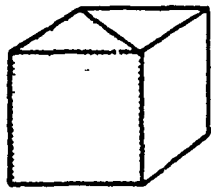
1/3							
0	1/3						
0	-1/12	1/3					
-1/12	0	0	1/3				
0	-1/12	-1/12	-1/12	1/3			
-1/12	0	-1/12	-1/12	0	1/3		
-1/12	-1/12	0	-1/12	0	-1/12	1/3	
-1/12	-1/12	-1/12	0	-1/12	0	0	1/3

Figure 6.20. The empty cube volume cell.

Standard Cell 1

Half-Empty Wedge

$$1 < x + y < 2$$
$$0 < z < 1$$



Orientation: Right angle along line 7-8

Potential function:

i	N^i
1	0
2	$(1-y)(1-z)$
3	$(1-x)(1-z)$
4	$(x+y-1)(1-z)$
5	0
6	$(1-y)z$
7	$(1-x)z$
8	$(x+y-1)z$

W_{ij}

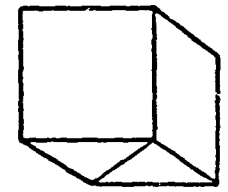
0							
0	1/4						
0	1/24	1/4					
0	-1/8	-1/8	5/12				
0	0	0	0	0			
0	0	-1/24	-1/8	0	1/4		
0	-1/24	0	-1/8	0	1/24	1/4	
0	-1/8	-1/8	-1/12	0	-1/8	-1/8	5/12

Figure 6.21. The half-empty wedge volume cell.

Standard Cell 2

Cube with diagonal line on one face

Orientation: Line from 2 to 3



Potential Function:

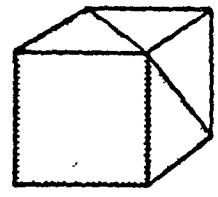
i	N^i
1	$(1-x-y)(1-z)\Theta(1-x-y)$
2	$[x\Theta(1-x-y)+(1-y)\Theta(x+y-1)](1-z)$
3	$[y\Theta(1-x-y)+(1-x)\Theta(x+y-1)](1-z)$
4	$(x+y-1)(1-z)\Theta(x+y-1)$
5	$(1-x)(1-y)z$
6	$x(1-y)z$
7	$(1-x)yz$
8	xyz

W_{ij}:

5/12							
-1/8	1/2						
-1/8	1/12	1/2					
0	-1/8	-1/8	5/12				
7/360	-37/360	-37/360	-23/360	1/3			
-11/180	-1/45	-19/180	-11/180	0	1/3		
-11/180	-19/180	-1/45	-11/180	0	-1/12	1/3	
-23/360	-37/360	-37/360	7/360	-1/12	0	0	1/3

Figure 6.22. The empty special cell.

Standard Cell 3



Tetrahedron

$2 < x + y + z < 3$

Orientation: Empty corner at point 8

Potential Function:

i	N^i
1	0
2	0
3	0
4	1-z
5	0
6	1-y
7	1-x
8	x+y+z-2

W_{ij}:

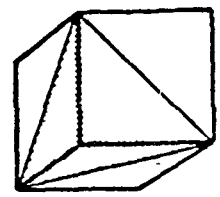
0							
0	0						
0	0	0					
0	0	0	1/6				
0	0	0	0	0			
0	0	0	0	0	1/6		
0	0	0	0	0	0	1/6	
0	0	0	-1/6	0	-1/6	-1/6	1/2

Figure 6.23. The tetrahedron volume cell.

Standard Cell 4

Truncated Cube

Orientation: 000 corner (point 1) missing



Potential Function:

i	N^i
1	0
2	
3	exercise
4	for
5	reader
6	
7	
8	

W_{ij}:

0							
0	5/12						
0	1/72	5/12					
0	-11/120	-37/360	13/36				
0	1/72	1/72	-1/9	5/12			
0	-37/360	-1/9	-7/180	-11/120	13/36		
0	-1/9	-11/120	-7/180	-37/360	-7/180	13/36	
0	-5/36	-5/36	1/45	-5/36	1/45	1/45	7/20

Figure 6.24. The empty truncated cube volume cell.

SPCWGT

Purpose: Calculates potential coefficients for surface and special points associated with volume cells. (See Figures 6.19-6.24.)

Calling Sequence: SUBROUTINE SPCWGT (LTBL,NX,NY,NZ)

Called By: OBJDEF

SRFPTS

Purpose: Identifies surface points and computes potential coefficients associated with dielectric layers and vacuum gaps. Identifies multiconductor points.

Calling Sequence: SUBROUTINE SRFPTS (LTBL,NX,NY,NZ)

Called By: OBJDEF

7. CODE DESCRIPTION — POTENTIAL SECTION

7.1 CONJUGATE GRADIENT POTENTIAL SOLUTION

Potentials at grid points and on each of the conductors are solved using a conjugate gradient (CG) iteration scheme.[9, 10] Either of two slightly different solution algorithms may be specified by the user. The first, referred to as algorithm 0, is slightly faster than the second and requires one less external storage file, but is less convenient to use because there is no straightforward way to determine quality of convergence. A generally decreasing trend in the residual may often be masked by large short-term oscillations over several orders of magnitude. The second algorithm, however, referred to as algorithm 1, constructs a monotonically decreasing residual quantity which allows the user to more accurately judge the quality of the potential convergence at any point in the potential solution. In both cases, the residuals and other relevant quantities are printed at each potential iteration and also printer-plotted over all iterations at the end of the potential iteration loop for ease of examination.

Although each actual application will demand specific judgments, the following guidelines will help the user in deciding which algorithm to use: (1) Algorithm 1 is recommended for most applications. Where a new or unfamiliar case is being investigated, the monotonic residual is a great convenience in judging accuracy of the potentials. The extra computing time involved in this algorithm is small. (2) In certain cases where many runs have been made on a given case or on similar cases, and where user judgment as to how many iterations will produce usable potentials is fairly solid, algorithm 0 would be a proper choice if costly large-scale production runs are to be made. In this case, algorithm 1's extra overhead in maintaining the additional external storage file and communicating with it may add a small (percentage-

wise) but significant amount of dollars to the total cost. In addition, although algorithm 1 yields a monotonic residual and algorithm 0 may yield an oscillating but generally decreasing residual, the actual quality of convergence of algorithm 0 at any given potential iteration will quite likely be the same as that derived from algorithm 1. The difference is simply that the user obtains a clearer picture of the quality of convergence with algorithm 1. When any uncertainty about the convergence of the potentials exists or is expected, algorithm 1 should definitely be used.

Requirements of the conjugate gradient solution technique are a system of linear equations whose coefficient array is both symmetric and positive definite. Our 3-D Poisson equation system is arranged to meet these requirements. Given a system of N unknowns, the conjugate gradient equations will converge to an exact solution in N iterations and will apparently tend to converge in most cases to a practical solution after a few times $\sqrt[3]{N}$ iterations.

The solution equations for algorithm 0 are as follows:

Given

$$Ap = ROUS \tag{7.1}$$

where A is a coefficient array, p is the potential (solution) vector, and ROUS is a boundary condition vector; we need to maintain storage for vectors (Ap), p, ROUS, two more vectors, r and u, and two scalars, α and β. Solution proceeds as follows:

Initialization: $$u^o = ROUS - (Ap)^o \tag{7.2}$$

$$r^o = u^o \tag{7.3}$$

$$n = 0 \tag{7.4}$$

Iteration Loop: $(Au)^n = (A)(u^n)$ (7.5)

$$\alpha^n = \frac{r^n \cdot r^n}{u^n \cdot (Au)^n} \tag{7.6}$$

$$p^{n+1} = p^n + \alpha^n u^n \tag{7.7}$$

$$r^{n+1} = r^n - \alpha^n (Au)^n \tag{7.8}$$

$$\beta^n = -r \cdot (Au)^n / u^n \cdot (Au)^n \tag{7.9}$$

$$u^{n+1} = r^{n+1} + \beta^n u^n \tag{7.10}$$

$$n = n + 1 \tag{7.11}$$

Repeat iteration loop

Figure 7.1 illustrates in block diagram form a gross overview of the routines called from subroutine POTENT (potential solver routine) which accomplish the conjugate gradient solution for algorithm 0.

The coefficient array A is never explicitly formed; only elements of the coefficient product arrays $(Ap)^o$ or $(Au)^n$ are ever formed and stored. Even so, we must form, store, and update for each iteration five vectors with length equal to the number of unknowns in the system. Assuming a moderately fine cell spacing of 17 x 17 x 33 points per grid, and assuming a nesting of three or four of these grids, it is clear that we are dealing with significantly large storage requirements (5 x 17 x 17 x 33 = 47,685 vector elements for the innermost grid <u>alone</u>, not counting up to seven additional unknowns for the conductor potentials). Obviously, use of the conjugate gradient scheme involves a nontrivial data management system in order to treat a problem of this scope efficiently and still execute in ~65K on a UNIVAC 1108 (or 1110) computer system.

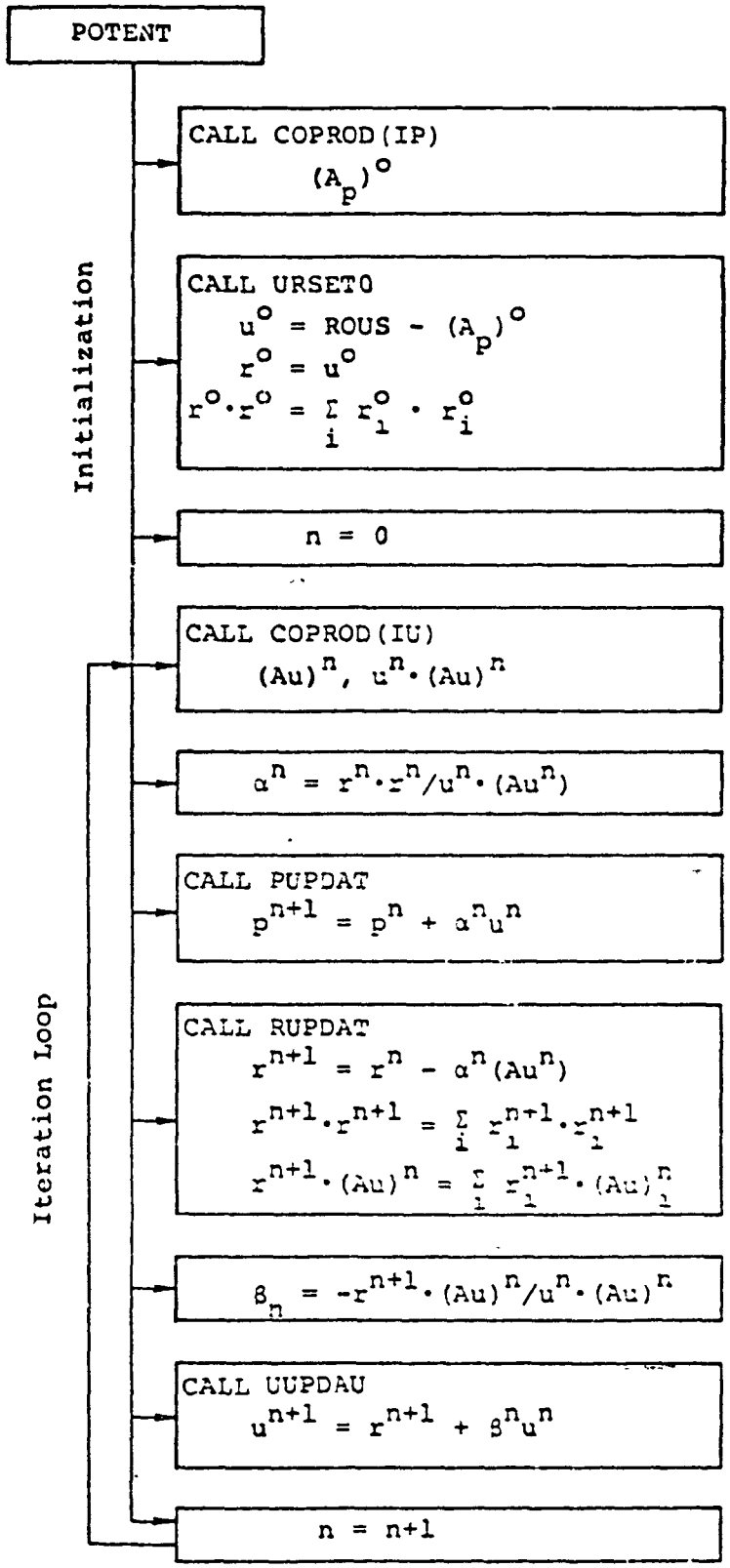


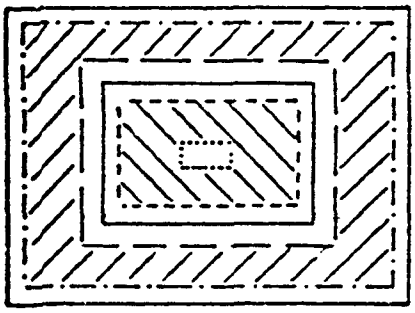
Figure 7.1. Algorithm 0 block diagram.

To minimize core storage requirements we require that as few as possible of the five necessary arrays be in core at any given time, and that as few grids worth of data for any of those five quantities be in core at any given time. (One "grid's worth" of data is NX•NY•NZ numbers which are the values of one of the five quantities at all points of any one of the several nested NX x NY x NZ grids.)

Five external files (drum, disc or tape) are utilized for storage of the five large vector quantities; one additional file acts as a "rotating spare" for use in the efficient updating of the p, r and u arrays each iteration. These files are designated by variables IP, IR, IU, IAUN, IROUS and ISPARE which contain the external file unit numbers. In all cases, the quantities are stored on their respective files beginning with inner grid data and working outward through the nested grids to the outermost grid data at the end of the file. All data transfer between these files and the code buffer arrays is done by a subroutine called MOVDAT. MOVDAT transfers data both into core from external files and vice versa, and in all cases uses efficient block transfer routines to move an entire grid's worth of data at one time.

Figure 7.2 illustrates the sectioning of the nested grids for two adjacent layers. The limiting case for simultaneous core storage of grid data occurs in subroutine COPROD which, as shown in Figure 7.2, calculates either the $(Ap)^o$ array (initialization) or the $(Au)^n$ array (within iteration loop). For purposes of explanation, we will speak of the resultant coefficient product array here simply as $(Au)^n$. A self-consistent starting point at an arbitrary grid in the middle of the next would assume I-A and all points within it have already been dealt with. Calculation of Area I-B of $(Au)^n$ requires only two grids worth of simultaneous storage: one array containing . u data for that grid (remember that the A matrix is never formed explicitly – its elements are

A: Inner edge of a grid
B: Interior space of a grid
C: Outer edge of a grid
I: Inner grid of the two
O: Outer grid of the two



Key:

———— Grid boundaries

..... Area I-A Inner Edge of Inner Grid

\\\\\ Area I-B Interior Space of Inner Grid

- - - - - - - Area I-C Outer Edge of Inner Grid

— — — Area O-A Inner Edge of Outer Grid

/////// Area O-B Interior Space of Outer Grid

—·—·— Area O-C Outer Edge of Outer Grid

Figure 7.2. Simplified two-dimensional sectioning of two adjacent grids.

essentially calculated one at a time as needed), and a second array into which are placed the resultant elements of $(Au)^n$ for that grid. However, the calculation of elements of $(Au)^n$ for either Area I-C or Area O-A requires u data for both grids to be present simultaneously. We place these data in buffer arrays BUF1 and BUF2. Fortunately, we need only maintain one grid's worth of resultant storage for $(Au)^n$ at any one time, since once Areas I-A, I-B and I-C of $(Au)^n$ have been calculated, then BUF3, the array containing the resultant $(Au)^n$, can be written out onto its external storage file by MOVDAT. Then, with the same two grids' worth of u data in BUF1 and BUF2, the Area O-A elements of $(Au)^n$ may be calculated and placed in BUF3, overwriting the last grid's data which has just been written out. The whole scheme, given several grids in the problem, is essentially a sort of piggy-back-leapfrog data manipulation which might be diagrammed as in Figure 7.3.

Thus we see that the most data we need ever have in core at any one time is three grids' worth; two of u (or p in the initialization), and one of Au^n (or Ap^o). The synopsis of subroutine COPROD presented in Figure 7.4 illustrates the actual mechanism of implementing what is diagrammed in Figure 7.3 including all data transfers between core and external storage files.

All other routines used by the conjugate gradient potential solver require at most two grid's worth of data at any one time. A synopsis of PUPDAT, a representative routine of this group, is presented in Figure 7.5.

Subroutines RUPDAT, UUPDAT and URSETO follow essentially the same pattern as shown here. The only concept of note in the three update routines is the use of the "rotating spare" file. For each of PUPDAT, RUPDAT, and UUPDAT, a quantity is being used to update itself: e.g., $p^{n+1} = p^n + \alpha^n u^n$. Recall that despite the simplicity of this equation, each of

Grid Index	U-Data Blocks	Grid Pair	
1		0	Calculate $(Au)^n$ for 1-B (Area A is not meaningful for the innermost grid.)
2		1	Calculate $(Au)^n$ for 1-C Write out $(Au)^n$ to unit IAUN Calculate $(Au)^n$ for 2-A, 2-B
3		2	Calculate $(Au)^n$ for 2-C Write out $(Au)^n$ to unit IAUN Calculate $(Au)^n$ for 3-A, 3-B
4		3	Calculate $(Au)^n$ for 3-C Write out $(Au)^n$ to unit IAUN Calculate $(Au)^n$ for 4-A, 4-B
5		4	Calculate $(Au)^n$ for 4-C Write out $(Au)^n$ to unit IAUN Calculate $(Au)^n$ for 5-A, 5-B
			Write out $(Au)^n$ to unit IAUN

(Area 5-C, the outer edge of the outermost grid, is a special case treated elsewhere by the code and need not be filled in here.)

Figure 7.3. Data manipulation in the COPROD routine in a five grid problem.

Subroutine COPROD(IA)

IA is an I/O unit number containing the file identifier for either the p array (initialization) or the u array (iteration loop). The description here assumes we are dealing with the u array for this call.

```
Call MOVDAT:   Innermost grid u data from file
               IU → BUF1

Call ISPACE:   (Au)^n for Area 1-B → BUF3
               (Area 1-A has no meaning.)

Loop over nested grids:  DO IG=2,NG
    N1 = 1
    N2 = NX*NY*NZ+1
If loop index IG is odd, switch values of N1 and N2
Call MOVDAT:   Next grids u data → BUF1(N2)
Call IRCALL:   Calculate Area I-C of (Au)^n using u
               data for two adjacent grids in BUF1(N1)
               and BUF1(N2); results go in BUF3
Call MOVDAT:   Write completed inner grid (Au)^n data
               (Areas I-A, I-B and I-C) from
               BUF3 → File IAUN
Call ORCALL:   Calculate Area O-A of (Au)^n using u
               data for two adjacent grids; results
               go in BUF3, overwriting previous con-
               tents
    Repeat loop for next grid pair
Call MOVDAT:   Write outermost grid (Au)^n data from
               BUF3 → File IAUN
Rewind IA (IP or IU)
Rewind IAUN
Return
```

Figure 7.4. Synopsis of subroutine COPROD.

PUPDAT does the equation $p^{n+1} = p^n + \alpha^n u^n$

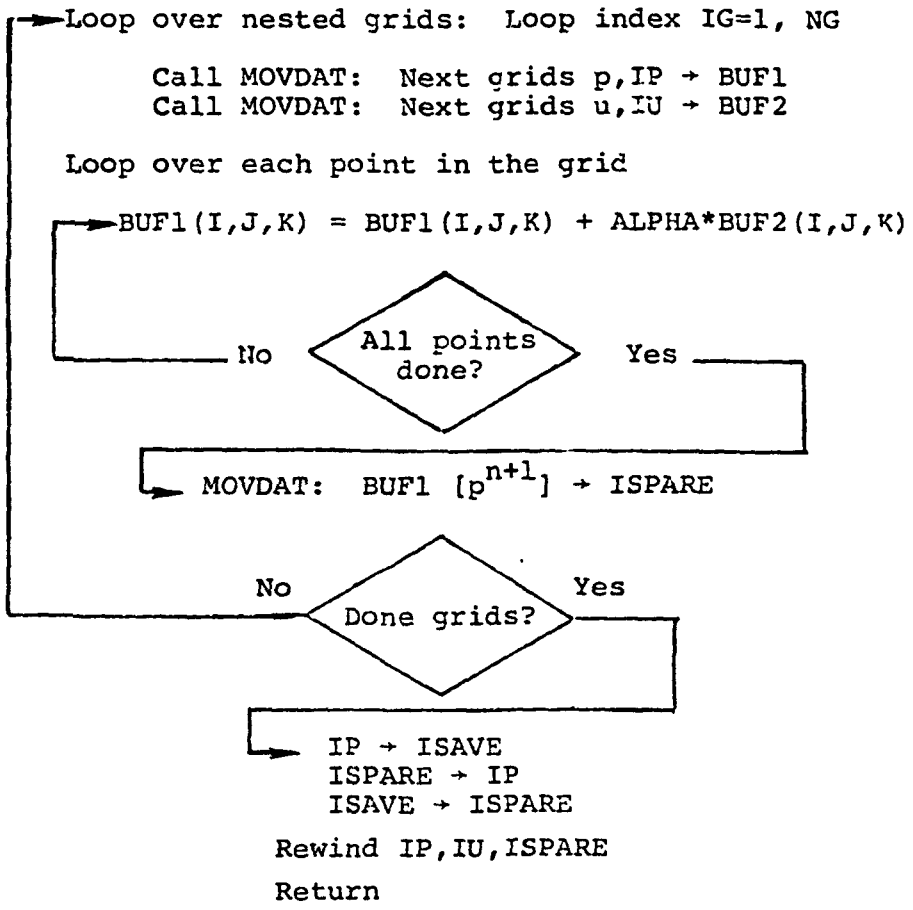


Figure 7.5. Synopsis of subroutine PUPDAT (representative of RUPDAT and UUPDAT as well).

p and u is actually a vector of perhaps 38,148 elements (for a four grid problem), treated in blocks of 9537 elements at a time (one grid's worth for a 17 x 17 x 33 grid). As is illustrated in Figure 7.5, one grid's worth of p elements and one of r elements are brought into arrays BUF1 and BUF2. The updated p^{n+1} elements for that grid are calculated and then must be written out onto some external storage file. (Writing them into the unused BUF3 array would not eliminate the problem, which is one of preserving proper ordering and spacing of data on the external storage files.) The data obviously cannot be written back into the p file from which p^n was just read, or the next grid's worth of data would be overwritten. One could devise a cumbersome rewind and space-forward-to-flag technique, but the coding work and, more significantly, data read-write time involved in such an approach would not be at all justified given the following alternative: The updated p^{n+1} is written out onto whatever unit is designated as unit ISPARE at that time. The data is written out in the same natural order in which it was read in and calculated, one grid at a time, beginning with the inner grid data. When all computations are finished, we have old file IP at the end of its p^n data, file IU at the end of its u^n data, and file ISPARE at the end of its updated p^{n+1} data. To recreate the natural situation expected by the rest of the code — new p data on IP, u data on IU, and ISPARE a free file with no longer needed data on it, we need only switch the values held by variables IP and ISPARE. Since the values of IP, ISPARE, IR, IU, IAUN and IB are known to the rest of the code, and since the old p^n values on the new file ISPARE are indeed no longer needed for any calculations, we can do this with impunity. All that remains is to rewind the three files IP, IU and ISPARE so that at the start of any subsequent routine, we are situated at the opening (innermost grid) data for each file, as is required by all routines in the code.

We see, then, that the four I/O unit variables IP, IR, IU and ISPARE do, in fact, "rotate around" the set of identifiers for the corresponding external files through the course of several iterations, and no ambiguity ever exists as to which file contains which data set. In this way, the trivial sacrifice of maintaining one more external file during the course of a run allows simple and efficient coding for and execution of the three array updates for p, r and u.

The execution of algorithm 1 is quite similar, but involves one more vector which we call y, stored on unit IY, and an additional scalar, c.

The equations for algorithm 1 are as follows:

Initialization:

$$u^o = ROUS - (Ap)^o \tag{7.12}$$

$$r^o = u^o \tag{7.13}$$

$$y^o = (Ap)^o \tag{7.14}$$

$$c^o = 1 \tag{7.15}$$

Iteration Loop:

$$(Au)^n = (A)\ (u^n) \tag{7.16}$$

$$\alpha^n = \frac{r^n \cdot r^n}{u^n \cdot (Au)^n} \tag{7.17}$$

$$p^{n+1} = p^n + \alpha^n\ p^n \tag{7.18}$$

$$r^{n+1} = r^n - \alpha^n\ (Au)^n \tag{7.19}$$

$$\beta^n = -r \cdot (Au)^n / u^n \cdot (Au)^n \tag{7.20}$$

$$c^{n+1} = 1 + \beta^n\ c^n \tag{7.21}$$

Calculate Monotonic Residual:

$$x \cdot \tilde{r} = u^n \cdot u^n / c^2 \tag{7.22}$$

$$y^{n+1} = ROUS - r^{n+1} + \beta^n y^n \tag{7.23}$$

$$u^{n+1} = c^{n+1} ROUS - y^{n+1} \tag{7.24}$$

$$n = n + 1$$

Repeat Iteration Loop

Figure 7.6 illustrates in block diagram form the execution of algorithm 1. Aside from the calculation of the monotonic residual (which has no effect on the solution vector) the only differences in execution between the two algorithms are the initialization and updating of the y vector and c scalar, and a change in the updating of the u vector. Subroutines YINIT and YUPDAT perform the y vector operations. Subroutine UUPDAT updates the u vector for algorithm 1, while subroutine UUPDAU updates the u vector for algorithm 0. In addition, file IY now rotates unit numbers along with IP, IR, IU and ISPARE.

Following is a complete documented list of all subroutines involved in the potential solution. Subroutine arguments not defined under the routine in which they appear are general quantities which are defined in the variable glossary.

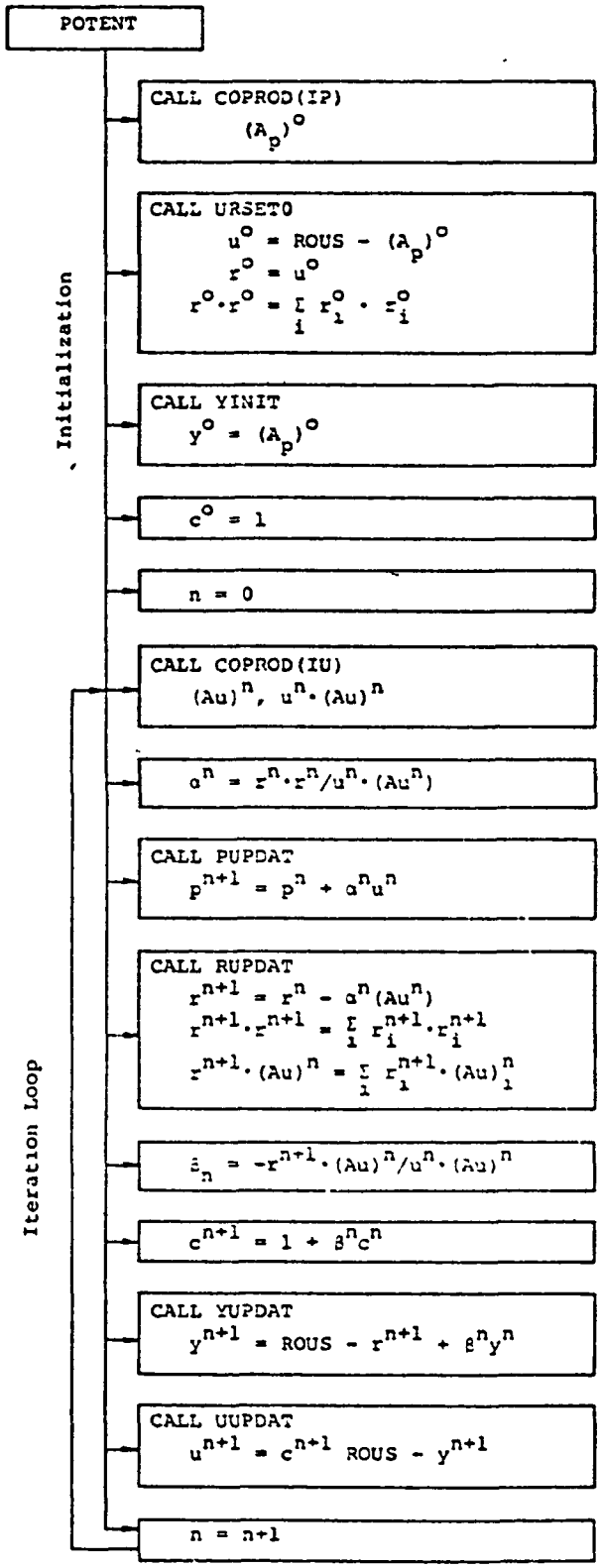


Figure 7.6. Algorithm 1 block diagram.

7.2 SUBROUTINE DESCRIPTIONS

COPROD

Calling Sequence: SUBROUTINE COPROD (IA, IAUN, BUF1, BUF3, NG, NX, NY, NZ, P3, W4, UDOTAU, AUNCON, UPCOND, IOBJ, W, LIST, WPCOND, PMCND, SWPSSC, CIJ, CIJSUM, MBIAS, MFIX)

Called By: POTENT (in two places)

Local Variables: IA: COPROD takes the product of the coefficient array A with whatever vector is on external storage unit IA. In the initial call to COPROD, IA = IP, the unit storing the (at that time) initial guess for the potentials. In the iteration loop call to COPROD, IA = IU, the unit storing the u^n vector.

Purpose: COPROD computes the product of the linear equation coefficient array A with either of p^o or u^n, depending on whether the call to COPROD is the initial call in POTENT or the call within the potential iteration loop. COPROD also calculates $u^n \cdot (Au)^n$ adding terms into the dot product one at a time, as it calculates the individual terms of $(Au)^n$.

Internal Organization: COPROD moves the inner grid's worth of data from IA into BUF1, and calls ISPACE and OBJSPC to compute the coefficient product values at grid points within the 1-B (see Figure 7.2) grid area (placed in BUF3).

A loop over the number of nested grids follows. This loop reads in the next grid's IA data, calls IRCALL to calculate product values at grid points within area 1-C (outer edge of inner grid), writes the completed inner grid $(Au)^n$ data from BUF3 onto file IAUN, and finally, calls ORCALL to

calculate product values for points within grid areas 2-A and 2-B (inner edge of outer grid and interior space of outer grid) after BUF3 has been re-initialized to zero). The loop repeats itself for all grids, at each point having two adjacent grid's IA data plus one grid's IAUN data in core at one time, and making its way one grid at a time outward towards the outermost grid pair. This procedure is diagrammed in Figure 7.3.

Finally, both the IA and IAUN files are rewound.

ICORN

Calling Sequence: SUBROUTINE ICORN (P1, P2, BUF3, NX, NY, NZ, P2D, W4, UDOTAU)

Called By: IRCALL

Local Variables: P1: Storage space BUF1

P2: Storage space BUF2

P2D: Storage space P3 (scratch storage)

Purpose: Using the trilinear interpolation scheme, ICORN computes the coefficient product values for the grid points of the outer edge of the inner grid of the current pair (grid area I-C) which are the eight outer corner points of the inner grid.

The interpolation requires both inner grid (P1) and outer grid (P2) data for u^n (or p^o). Coefficient product values are placed in BUF3.

INEDGX

Calling Sequence: SUBROUTINE INEDGX (P1, P2, BUF3, NX, NY, NZ, P2D, W4, UDOTAU)

Called By: IRCALL

Local Variables: P1: Storage space BUF1

P2: Storage space BUF2

P2D: Storage space P3 (scratch storage)

Purpose: Using the trilinear interpolation scheme, INEDGX computes coefficient product values for the grid points of the outer edge of the inner grid of the current pair (grid area I-C) which lie on edges (where two planes meet) parallel to the x-axis. Corner points on these edges are not treated here.

The interpolation requires both inner grid (P1) and outer grid (P2) data for u^n (or p^o). Coefficient product values are placed in BUF3.

INEDGY

Calling Sequence: SUBROUTINE INEDGY (P1, P2, BUF3, NX, NY, NZ, P2D, W4, UDOTAU)

Called By: IRCALL

Local Variables: P1: Storage space BUF1

P2: Storage space BUF2

P2D: Storage space P3 (scratch storage)

Purpose: Using the trilinear interpolation scheme, INEDGY computes coefficient product values for the grid points of the outer edge of the inner grid of the current pair (grid area I-C) which lie on edges (where two planes meet) parallel to the y-axis. Corner points on these edges are not treated here.

The interpolation requires both inner grid (P1) and outer grid (P2) data for u^n (or p^o). Coefficient product values are placed in BUF3.

INEDGZ

Calling Sequence: SUBROUTINE INEDGZ (P1, P2, BUF3, NX, NY, NZ, P2D, W4, UDOTAU)

Called By: IRCALL

Local Variables: P1: Storage space BUF1

P2: Storage space BUF2

P2D: Storage space P3 (scratch storage)

Purpose: Using the trilinear interpolation scheme, INEDGZ computes coefficient product values for the grid points of the outer edge of the inner grid of the current pair (grid area I-C) which lie on edges (where two planes meet) parallel to the z-axis. Corner points on these edges are not treated here.

The interpolation requires both inner grid (P1) and outer grid (P2) data for u^n (or p^o). Coefficient product values are placed in BUF3.

IPLANX

Calling Sequence: SUBROUTINE IPLANX (P1, P2, BUF3, NX, NY, NZ, P2D, W4, UDOTAU)

Called By: IRCALL

Local Variables: P1: Storage space BUF1

P2: Storage space BUF2

P2D: Storage space P3 (scratch storage)

Purpose: Using the trilinear interpolation scheme, IPLANX computes coefficient product values for two plane sections of the outer edge of the inner grid of the inner pairs (grid area I-C): (1) the plane of grid points on the +x end of the inner grid, except for the edge points and corner points, and (2) the plane of grid points on the -x end of the inner grid, except for the edge points and corner points.

The interpolation requires both inner grid (P1) and outer grid (P2) data for u^n (or p^o). Coefficient product values are placed in BUF3.

IPLANY

Calling Sequence: SUBROUTINE IPLANY (P1, P2, BUF3, NX, NY, NZ, P2D, W4, UDOTAU)

Called By: IRCALL

Local Variables: P1: Storage space BUF1

P2: Storage space BUF2

P2D: Storage space P3 (scratch storage)

Purpose: Using the trilinear interpolation scheme, IPLANY computes coefficient product values for two plane sections of the outer edge of the inner grid of the current pairs (grid area I-C): (1) the plane of grid points on the +y end of the inner grid, except for the edge and corner points, and (2) the plane of grid points on the -y end of the inner grid except for the edge points and corner points.

The interpolation requires both inner grid (P1) and outer grid (P2) data for u^n (or p^o). Coefficient product values are placed in BUF3.

IPLANZ

Calling Sequence: SUBROUTINE IPLANZ (P1, P2, BUF3, NX, NY, NZ, P2D, W4, UDOTAU)

Called By: IRCALL

Local Variables: P1: Storage space BUF1

P2: Storage space BUF2

P2D: Storage space P3 (scratch storage)

Purpose: Using the trilinear interpolation scheme, IPLANZ computes coefficient product values for two plane sections of the outer edge of the inner grid of the current pair (grid area I-C): (1) the plane of grid points on the +z end of the inner grid, except for the edge and corner points, and (2) the plane of grid points in the -z end of the inner grid, except for edge and corner points.

The interpolation requires both inner grid (P1) and outer grid (P2) data for u^n (or p^o). Coefficient product values are placed in BUF3.

IRCALL

Calling Sequence: SUBROUTINE IRCALL (BUF1, BUF2, BUF3, NX, NY, NZ, P3, W4, UDOTAU)

Called By: COPROD

Purpose: IRCALL calls the series of I prefix routines which compute coefficient product values for grid area I-C in Figure 7.2 (outer edge of the inner grid of the current pair).

The routines called by IRCALL are (in sequence):

IPLANX
IPLANY
IPLANZ
INEDGX
INEDGY
INEDGZ
ICORN

ISPACE

Calling Sequence: SUBROUTINE ISPACE (P, BUF3, NX, NY, NZ, UDOTAU)

Called By: COPROD

Purpose: ISPACE calculates coefficient product values at grid points in the innermost grid of the nested grid system, excepting those surface points and special points on or around the satellite which we defined in the OBJDEF section and which are treated in OBJSPC, and excepting the points on the outer edge of the inner grid which are treated by the routines called by IRCALL.

OBJSPC

Calling Sequence: SUBROUTINE OBJSPC (BUF1, BUF3, NX, NY, NZ, UDOTAU, AUNCON, UPCOND, IOBJ, W, LIST, WPCOND, PMCND, SWPSSC, CIJ, CIJSUM, MBIAS, MFIX)

Called By: COPROD

Purpose: OBJSPC calculates coefficient product values for those grid points of the inner grid on or around the satellite which are defined by the OBJDEF section as being either surface points or special points.

OBJSPC also calculates coefficient product values for the unbiased or unfixed conductor potentials.

OCORN

Calling Sequence: SUBROUTINE OCORN (P1, P2, BUF3, NX, NY, NZ, W4, UDOTAU)

Called By: ORCALL

Local Variables: P1: Storage space BUF1

P2: Storage space BUF2

Purpose: Using the trilinear interpolation scheme, OCORN computes coefficient product values for grid points at the corners of the inner edge of the outer grid of the current pair (grid area O-A).

The interpolation requires both inner grid (P1) and outer grid (P2) data for u^n (or p^o). Coefficient product values are placed in BUF3.

OPLANX

Calling Sequence: SUBROUTINE OPLANX (P1, P2, BUF3, NX, NY, NZ, W4, UDOTAU)

Called By: ORCALL

Local Variables: P1: Storage space BUF1

P2: Storage space BUF2

Purpose: Using the trilinear interpolation scheme, OPLANX computes coefficient product values for two sections of the inner edge of the outer grid of the current pair (grid area O-A): (1) the plane of grid points on the +x side adjacent to the inner grid of the pair, and (2) the plane of grid points in the -x side adjacent to the inner grid of the pair. In both cases, corner points and the edge points where two planes meet are excepted.

The interpolation requires both inner grid (P1) and outer grid (P2) data for u^n (or p^o). Coefficient product values are placed in BUF3.

OPLANY

Calling Sequence: SUBROUTINE OPLANY (P1, P2, BUF3, NX, NY, NZ, W4, UDOTAU)

Called By: ORCALL

Local Variables: P1: Storage space BUF1

P2: Storage space BUF2

Purpose: Using the trilinear interpolation scheme, OPLANY computes coefficient product values for two sections of the inner edge of the outer grid of the current pair (grid area O-A): (1) the plane of grid points on the +y side adjacent to the inner grid of the pair, and (2) the plane of grid points on the -y side adjacent to the inner grid of the pair. In both cases, corner points and edge points where two planes meet are excepted.

The interpolation requires both inner grid (P1) and outer grid (P2) data for u^n (or p^o). Coefficient product values are placed in BUF3.

OPLANZ

Calling Sequence: SUBROUTINE OPLANZ (P1, P2, BUF3, NX, NY, NZ, W4, UDOTAU)

Called By: ORCALL

Local Variables: P1: Storage space BUF1

P2: Storage space BUF2

Purpose: Using the trilinear interpolation scheme, OPLANZ computes coefficient product values for two sections of the inner edge of the outer grid of the current pair (grid area O-A): (1) the plane of grid points on the +z side adjacent to the inner grid of the pair, and (2) the plane of grid points in the -z side adjacent to the inner grid of the pair. In both cases, corner points and edge points where two planes meet are excepted.

The interpolation requires both inner grid (P1) and outer grid (P2) data for u^n (or p^o). Coefficient product values are placed in BUF3.

ORCALL

Calling Sequence: SUBROUTINE ORCALL (BUF1, BUF2, BUF3, NX, NY, NZ, P3, W4, UDOTAU)

Called By: COPROD

Purpose: ORCALL first calls the series of O-prefix routines which compute coefficient product values for grid area O-A in Figure 7.2 (inner edge of outer grid of the current pair), and, second, calls subroutine SPACE to compute coefficient product values for grid area O-B (interior space of outer grid of the current pair).

The routines called by ORCALL are (in sequence):

OPLANX
OPLANY
OPLANZ
OCORN
OUTEDG
SPACE

OUTEDG

Calling Sequence: SUBROUTINE OUTEDG (P1, P2, BUF3, NX, NY, NZ, P2D, W4, UDOTAU)

Called By: ORCALL

Local Variables: P1: Storage space BUF1

P2: Storage space BUF2

Purpose: Using the trilinear interpolation scheme, OUTEDG computes coefficient product values for grid points on the inner edge of the outer grid of the current pair (grid area O-A) which are on grid edges where two planes meet. Corner points of these edges are not treated here.

The interpolation requires both inner grid (P1) and outer grid (P2) data for u^n (or p^o). Coefficient product values are placed in BUF3.

POTENT

Calling Sequence: SUBROUTINE POTENT (BUF1, BUF2, BUF3, ICYC, RITER, UITER, PCITER, NITERP, ROUS, NX, NY, NZ, NG, QCOND, NC, W, LIST, WPCOND, PMCND, PCOND, IWARN, IALG)

Called By: TRILIN

Purpose: POTENT uses the iterative conjugate gradient technique described above to solve a set of linear equations whose unknowns are the potentials at all grid points and on each of the conductors, and the charges on each biased or fixed-potential conductor.

Internal Organization: POTENT places fixed-potential conductor potentials (set by input in array VFIX) into PCOND, and then forms some precalculable quantities (for use in OBJSPC) based on the WPCOND and PMCND weights and on the conductor relative capacitances. The first call to COPROD calculates A times p^o where p^o is the initial guess for the potentials for this run (determined by one of the initial guess options specified by user input, or, in the case of a restart, by the final potentials left over from the previous run).

Next, if IALG = 1, YINIT is called to initialize the IY file containing the y vector, and the ROUS vector is brought into core from file IROUS. PTROUS is called to correct the ROUS array at points in contact with one or more conductors, and the corrected ROUS is written back out onto file IROUS. Next, the ROUSCN array containing ROUS values for the conductor points is filled in, and URSETO is called to initialize the u^o and r^o conjugate gradient vectors, and to calculate $r^o \cdot r^o$.

The potential iteration loop follows, as described in Figure 7.6 above. COPROD is called to calculate A times u^n for the nth iteration and to compute the dot product $u^n \cdot (Au)^n$.

The scalar ALPHA is computed from $r^n \cdot r^n$ and $u^n \cdot (Au)^n$, and PUPDAT is called to update the solution vector p. Next, the r vector is updated by a call to RUPDAT which in addition calculates $r^{n+1} \cdot (Au)^n$ for use in computing BETA.

If IALG = 1, UDOTUC is called to generate $u^n \cdot u^n$ for use in calculation of the monotonic residual, and YUPDAT is called to update the y vector, UUPDAT is then called to perform the update operations on n which are required by algorithm 1.

If IALG = 0, UDOTUC, YUPDAT, and UUPDAT are skipped and UUPDAU is called instead. UUPDAU performs the u vector updating required by algorithm 0.

All convergence printer plot data for this iteration is stored, and the loop repeats itself until MAXITR is reached.

Following completion of the iteration loop (at which point a new potential for conductor 1 has been converged upon) the potential biases for all biased conductors are added to the conductor one potential and placed in their respective locations in PCOND.

Subroutine QCONCP is then called to calculate the new amounts of charge on any fixed potential or biased conductors as determined by the new set of potentials.

Finally, PTROUS is called again to reset the ROUS values to what they were prior to the corrections for points on conductors, so that ROUS may be used in its original form by subroutine CHARGE and its sequence of routines.

PTROUS

Calling Sequence: SUBROUTINE PTROUS (ROUS, LIST, WPCOND, PMCND, VBIAS, IOBJ, MBIAS, NX, NY, NZ, IRESET)

Called By: POTENT

Local Variables: IRESET: IRESET = 0 implies correct the ROUS array for biased conductor points. IRESET = 1 implies reset the ROUS array to what it was before PTROUS corrected it.

Purpose: The potential equations for all conductors biased relative to conductor 1 are added together with the equation for conductor 1, terms are collected, and a new single equation in one unknown (the potential of conductor 1) replaces the original set.

When this is done the equations for potentials at points in contact with biased conductors must also be adjusted. The WPCOND*ϕ_i term in each of these equations becomes WPCOND*(ϕ + V_{i1}) = WPCOND*ϕ_1 + WPCOND*V_{i1}. Since the second term is constant, it properly belongs on the right hand side of the equation, whose current value is held in ROUS for that point. When called with IRESET = 0, PTROUS makes the appropriate ROUS correction for all points in contact with one or more conductors. When called with IRESET = 1, PTROUS resets ROUS back to what it was before the first call to PTROUS, so that ROUS may be utilized in its original form by subroutine CHARGE, etc.

It should be noted that PTROUS corrects only the ROUS array passed to it; the writing of the corrected values to file IROUS is done by POTENT.

PUPDAT

Calling Sequence: SUBROUTINE PUPDAT (ALPHA, IP, IU, ISPARE, BUF1, BUF2, NG, NX, NY, NZ, NC, PCOND, UCOND, MBIAS, MFIX)

Called By: POTENT

Purpose: PUPDAT updates the linear equation solution vector P on file IP (containing system potentials) according to the equation

$$p^{n+1} = p^n + \alpha * u^n$$

The updated p^{n+1} data is written onto file ISPARE, one grid at a time, and when all data has been updated, the unit numbers IP and ISPARE are switched.

PUPDAT also updates the conductor potentials in array PCOND.

QCONCP

Calling Sequence: SUBROUTINE QCONCP (QCOND, PCOND, CIJ, CIJSUM, WPCOND, PHCND, BUF1, IP, NX, NY, NZ, IOBJ, MFIX, MBIAS)

Called By: POTENT

Purpose: Potentials for any conductors designated as fixed-potential or biased potential conductors are removed as unknowns from the set of linear equations solved by the conjugate gradient potential iteration system. Following convergence upon all other potentials of the system, proper biases are added to conductor 1's new potential and the resultant biased potentials are placed in the appropriate places in array PCOND (this is done in subroutine POTENT). The only unknowns remaining in the system at this point are the new amounts of charge on the biased or fixed conductors. QCONCP finds the amount of charge on conductor i according to the original equation for this conductor:

$$Q_i = \left(-\sum_F W_{Fi} + \sum_{j\neq 1} C_{ij}\right)\varphi_i - \sum_{j\neq 1} C_{ij}\phi_j + W_{Fi}\phi_F \cdot$$

QCONCP calculates the charge on each conductor and places it in the appropriate location in array QCOND.

RUPDAT

Calling Sequence: SUBROUTINE RUPDAT (ALPHA, IR, IAUN, ISPARE, BUF1, BUF2, NG, NX, NY, NZ, RDOTR, RDOTRS, NC, RCOND, AUNCON, RDOTAU, MBIAS, MFIX)

Called By: POTENT

Purpose: RUPDAT updates the conjugate gradient vector r on file IR according to the equation

$$r^{n+1} = r^n - \alpha * (Au)^n$$

The updated r^{n+1} data is written onto file ISPARE one grid at a time, and when all data has been updated, the unit numbers IR and ISPARE are switched.

RUPDAT also updates the conductor r values in array RCOND, and computes the two dot products $r^{n+1} \cdot r^{n+1}$ and $r^{n+1} \cdot (Au)^n$.

SPACE

Calling Sequence: SUBROUTINE SPACE (P, BUF3, NX, NY, NZ, W4, UDOTAU)

Called By: ORCALL

Local Variables: P: Storage space BUF2

Purpose: Using the trilinear interpolation scheme, SPACE computes coefficient product values for grid points in the interior space (neither on inner edge n or outer edge) of the outer grid of the current pair.

The interpolation requires both inner grid (P1) and outer grid (P2) data for u^n (or p^o). Coefficient product values are placed in BUF3.

UDOTUC

Calling Sequence: SUBROUTINE UDOTUC (IU, UDOTU, BUF1, NG, NX, NY, NZ, NC, UCOND)

Called By: POTENT

Purpose: UDOTUC computes the dot product $u^n \cdot u^n$ for use in computing the IALG = 1 monotonic residual dot product $\tilde{r} \cdot \tilde{r} = u \cdot u / c^2$.

UDOTUP

Calling Sequence: SUBROUTINE UDOTUP (UDOTAU, TPROD)

Called By: OPLANZ

Local Variables: TPROD: Coefficient product value for the grid point currently being treated by OPLANZ times u^n for this point.

Purpose: UDOTUP simply adds in the current term to $u^n \cdot (Au)^n$. In all other routines this simple operation is done internally, but in OPLANZ it caused compiler problems due to the overflowing of an internal compiler table (UDOTAU is a double-precision variable).

URSETO

Calling Sequence: SUBROUTINE URSETO (ROUS, IU, IR, IAUN, BUF1, BUF2, NG, NX, NY, NZ, RDOTR, NC, AUNCON, UCOND, RCOND, ROUSCN, MFIX, MBIAS)

Called By: POTENT

Purpose: Given the set of linear equations for the potential of the system, Ap = ROUS, and given the coefficient product Ap^o of A with the initial guess for the potentials, p^o, URSETO defines the u^o and r^o arrays on files IU and IR according to the equation

$$u^o = r^o = ROUS - Ap^o.$$

URSETO also calculates the initial dot product $r^o \cdot r^o$.

UUPDAT

Calling Sequence: SUBROUTINE UUPDAT (C, IU, IY, IR, IROUS, ISPARE, BUF1, BUF2, BUF3, NG, NX, NY, NZ, NC, UCOND, YCOND, RCOND, ROUSCN, MBIAS, MFIX)

Called By: POTENT

Purpose: For algorithm 1, UUPDAT updates the conjugate gradient vector u on file IU according to the equation

$$u^{n+1} = C*ROUS - y$$

The updated u^{n+1} data is written onto file ISPARE one grid at a time and when all data has been updated, the unit numbers IU and ISPARE are switched.

UUPDAT also updates the conductor u values in array UCOND.

UUPDAU

Calling Sequence: SUBROUTINE UUPDAU (BETA, ISPARE, BUF1, BUF2, NG, NX, NY, NZ, NC, UCOND, RCOND, MBIAS, MFIX)

Called By: POTENT

Purpose: For algorithm 0, UUPDAU updates the conjugate gradient vector u on file IU according to the equation

$$u^{n+1} = r^{n+1} + \beta * u^{n}$$

The updated u^{n+1} data is written onto file ISPARE one grid at a time and when all data has been updated, the unit numbers IU and ISPARE are switched.

UUPDAU also updates the conductor u values in array UCOND.

YINIT

Calling Sequence: SUBROUTINE YINIT (IY, IAUN, BUF1, NG, NX, NY, NZ, NC, YCOND, AUNCON, MFIX, MBIAS)

Called By: POTENT

Purpose: Initialize Y-vector data on IY file and YCOND array for IALG = 1 potential algorithm.

YUPDAT

Calling Sequence: SUBROUTINE YUPDAT (BETA, IY, IR, IROUS, ISPARE, BUF1, BUF2, BUF3, NG, NX, NY, NZ, NC, YCOND, RCOND, ROUSCN, MBIAS, MFIX)

Called By: POTENT

Purpose: For algorithm 1, YUPDAT updates the conjugate gradient vector y on file IY according to the equation

$$y^{n+1} = \beta * y^{n} + ROUS - r^{n+1}$$

The updated y^{n+1} data is written onto file ISPARE one grid at a time, and when all data has been updated, the unit numbers IY and ISPARE are switched.

YUPDAT also updates the conductor y values in array YCOND.

8. CODE DESCRIPTION — CHARGE SECTION

The CHARGE section of NASCAP makes use of all the information — potentials, geometry, environment and material properties — developed elsewhere in the NASCAP code. Also, in this section is most of the physical content.

CHARGE, the primary routine of this section, obtains the required information from external files, performs the LONGTIMESTEP option, and updates the charge density arrays. CALFLX calls routines to calculate the incident and emitted fluxes for each surface cell. Surface cell properties are decoded by GETCEL. For the test tank case, the incident flux is computed by SOURCE and ETNGUN; for the reverse trajectory case by PUSH. ELFLUX, PRFLUX, BKSCAT and SOLFLX compute emitted fluxes of electron- and proton-produced secondaries, backscattered electrons and photoelectrons, respectively. IOFLX performs printouts of these properties as requested. SHECAL (called from CHARGE) and PHOCUR perform the photosheath calculation. EFIELD and BFIELD provide the force fields required by the particle-tracking routines PUSH, ETNGUN and PHOCUR.

8.1 PRIMARY ROUTINES – CHARGE, CALFLX

CALFLX

Purpose: Calls SOURCE, PUSH, ETNGUN, ELFLUX, BKSCAT, PRFLUX, GETCEL, IOFLX. (See flow chart, Figure 8.1.)

Calling Sequence: SUBROUTINE CALFLX (ITYPE, PCOND, FLUXES, CNET, FLOW, IOBPLT, IPART)

ITYPE - NASCAP operating mode

PCOND - Array of conductor potentials

FLUXES - Array of net fluxes to surface cells

CNET - Net charging current

FLOW - Low electron emission for each surface cell

IOBPLT - LUN of OBJDEF output file

IPART - LUN of particle trajectory plot scratch file

Called By: CHARGE

CHARGE

Purpose: Primary routine for charge accumulation, transport and sharing for the NASCAP code. Performs LONGTIMESTEP option. (See flow chart, Figure 8.2.)

Calling Sequence: SUBROUTINE CHARGE (NNX, NNY, NNZ, NNG, ITYPE, QCOND, PCOND)

NNX,NNY,NNZ,NNG - Same as NX,NY,NZ,NG

ITYPE - NASCAP operating mode

QCOND - Array of charges on conductors

PCOND - Array of potentials on conductors

Called By: TRILIN

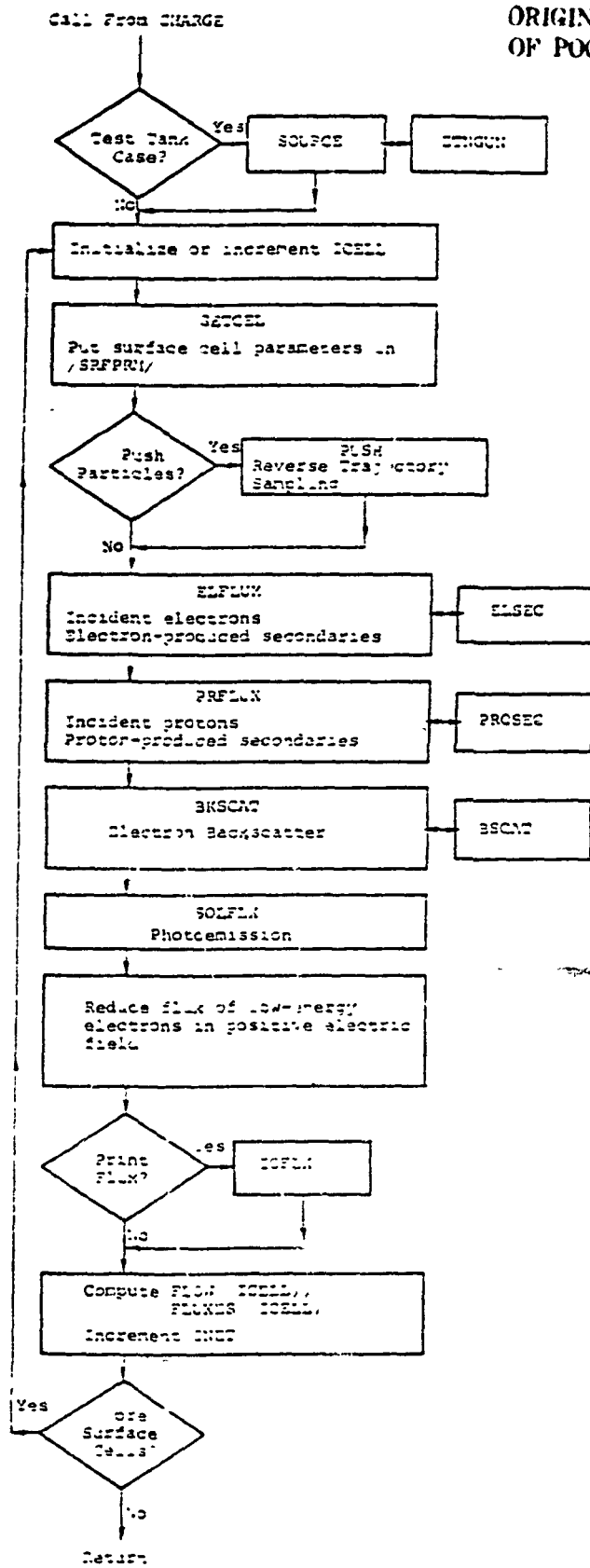


Figure 8.1. CALFLX flow chart.

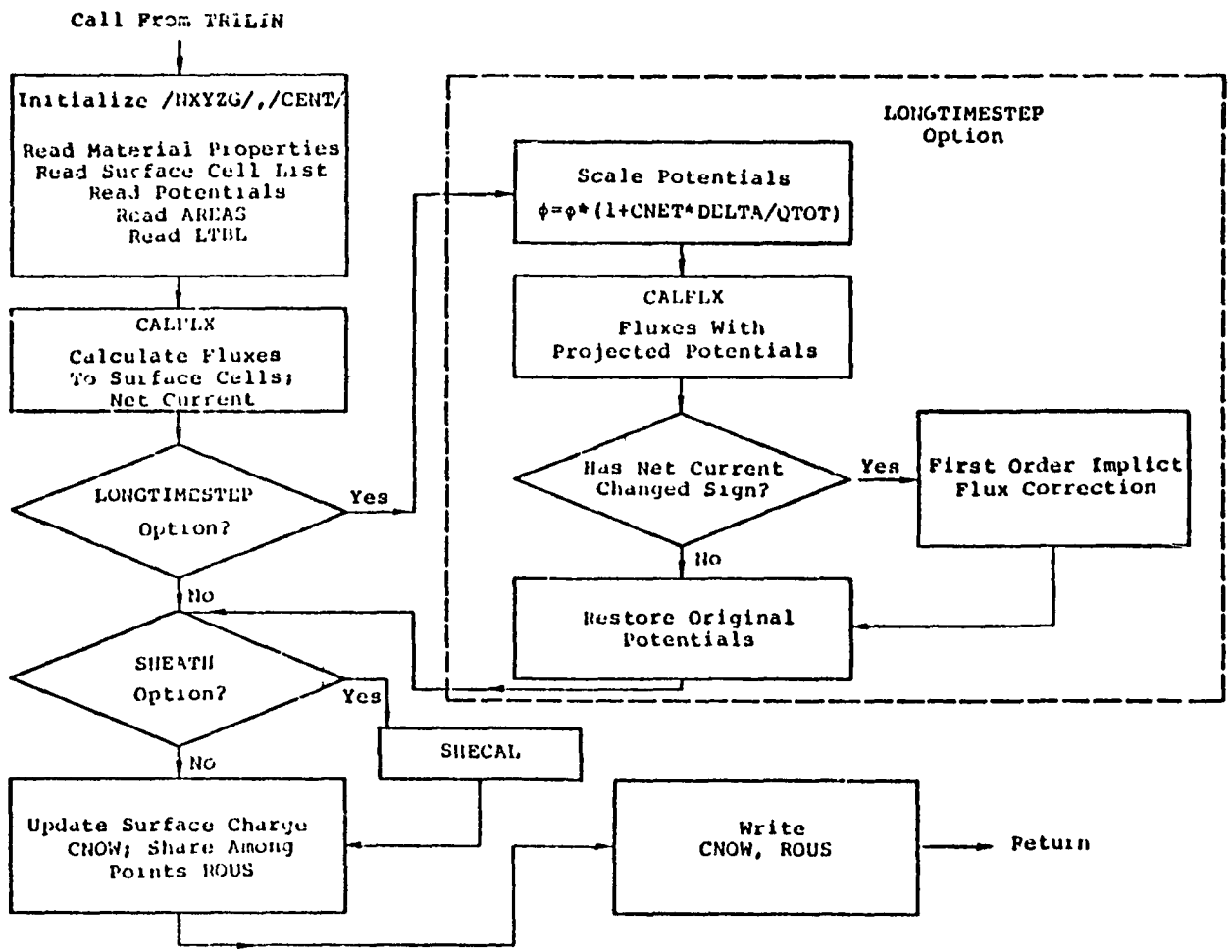


Figure 8.2. CHARGE flow chart.

8.2 TEST TANK ROUTINES

ETNGUN

Purpose: Calculate current density near object from tank beam.

Calling Sequence: ETNGUN (IOBPLT)
Input IOBPLT is the file which contains the object outline for plotting.

Output COMMON/TANK/CURRENT(3,17,17), IBMCAL, COM, CURRENT(K,I,J) = $J_K(I,J)$ the Kth component of the current density at grid location x = I, y = J.

Called By: SOURCE

Method: ETNGUN initially normalizes the net beam current to the input value. This is done by first integrating the current density and then scaling the input by the ratio of the desired current to integrated current. Next, the input spatial current density pattern is converted to current density as a function of angle at the beam source. For a given target size, only that part of the beam necessary to completely cover the target is followed. The determination of the angular spread necessary for this is calculated by a Rutherford scattering type formula. Finally, test particle trajectories are followed forward in time until they either hit the target or exit the inner mesh. If they hit the target, their contribution is added to the current density array.

MAGCMP

Purpose: Called by ETNGUN to correct velocity of electron for presence of constant magnetic field B during calibration.

Calling Sequence: SUBROUTINE MAGCMP (V, VO, RK, E, B)

V(3) - uncorrected velocity, to be returned corrected
VO - speed in code units
RK - Z-distance (normal) from source to calibration plane
E - electron energy (eV)
B(3) - constant magnetic field

Called By: ETNGUN

SOURCE

Purpose: Performs logical and I/O functions relevant to test tank particle tracking.

Calling Sequence: SUBROUTINE SOURCE (IOBPLT)
IOBPLT - LUN of OBJDEF output file

Called By: CALFLX

8.3 REVERSE TRAJECTORY ROUTINES

FREAD

Purpose: Reads DeForest's ATS-5 particle flux data. The unit number hour and day of the data are read off of IFLUX. The hour and day must be precisely as appears on the graphics in the environmental specification portion of the final report. If this is not true, there will be an attempt to read past the end of file on IUNIT. Appropriate averages are taken of the data to determine mean energies and densities.

Calling Sequence: SUBROUTINE FREAD (IFLUX)

Called By: FLXDEF

Local Variables: IUNIT: Unit where flux data is stored
RHOUR: Time of requested data
IDAY: Day of requested data

FSPACE

Purpose: FSPACE returns the phase space density from DeForest's data given the energy, velocity vector and species of a particle.

Calling Sequence: FUNCTION FSPACE (ENG, V, ISPEC)

Called By: PUSH

Local Variables: C2: Absolute value of cosine of angle between velocity vector and standard vector

S2: 1 - C2

PUSH

Purpose: For a given cell, calculate the incoming particle flux from a given ambient environment by the reverse trajectory technique. All test particles are emitted from the center of the cell. The selection of energies and angles are in common block FLUX. The actual flux densities are from FSPACE. The local flux is filled into F. EPOT(I) is the minimum final kinetic energy that a particle of type I can have upon impacting the object. That is, EPOT(I) = 0 if the object repels type I particles and EPOT equals the absolute value of the local potential if the object attracts particles of type I. (See Figure 8.3.)

Calling Sequence: SUBROUTINE PUSH (F, EPOT, ICELL, IPART)

Called By: CALFLX

Local Variables:

X(3):	Particle position
XO(3):	Center of the cell
V(3):	Particle velocity

SETAN

Purpose: Set up three standard 3 x 3 rotation matrices when the reference directions are the normals to <100>, <110> and <111> crystallographic planes. These are used in EFIELD and PUSH.

Calling Sequence: SUBROUTINE SETAN

Called By: PUSH

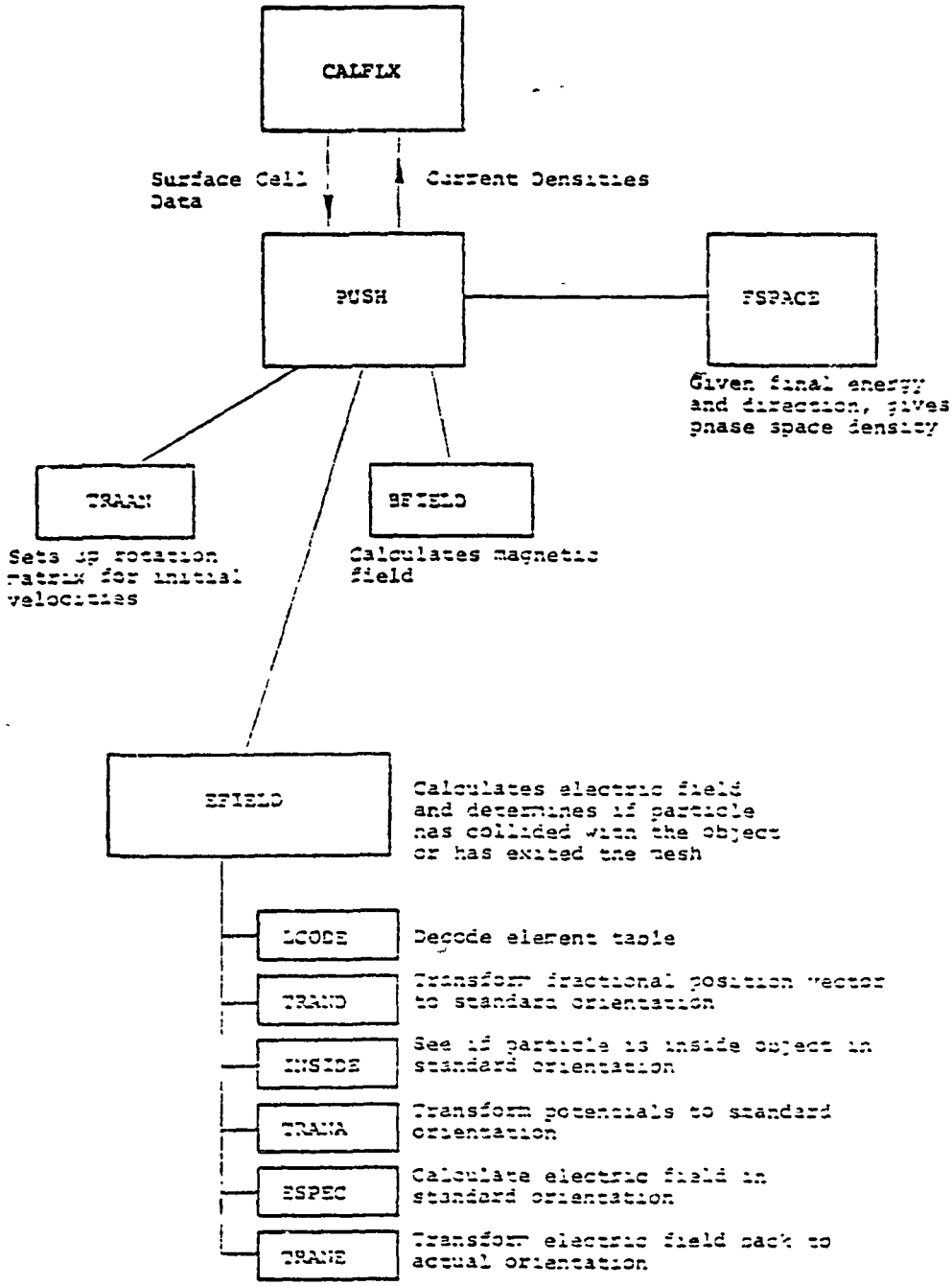


Figure 8.3. PUSH routine.

SETWE

Purpose: For a given number of energy bins, NENG, calculates the energies and weights such that each test particle would have equal weight if the incident flux were Maxwellian ($E \exp(-\beta E)$). Also gives exact result for exponential flux ($\exp(-\beta E)$).

Calling Sequence: SUBROUTINE SETWE

Called By: FLXDEF

SMFDEF

Purpose: Smooth raw ATS-6 data by simple linear blending to increase accuracy of average particle fluxes. The variable N sets how many data points on each side of a given data point will be included in the blended result.

Calling Sequence: SUBROUTINE SMFDEF (FDEF)

Called By: FLXDEF

SETMAX

Purpose: Constructs data for reverse trajectory sampling of a Maxwellian environment.

Calling Sequence: SUBROUTINE SETMAX (A, FDEF)

Called By: FLXDEF

8.4 FLUX AND EMISSION ROUTINES

BKSCAT

Purpose: Computes flux of backscattered electrons through Function BSCAT.

Calling Sequence: SUBROUTINE BKSCAT (ICELL, ITYPE, FIN, FOUT)

Called By: CALFLX

BSCAT

Purpose: Computes backscatter coefficient for electrons of energy (keV) incident normally (IOPT = 1), at angle THETA (IOPT = 2) or isotropically (IOPT = 4).

Calling Sequence: FUNCTION BSCAT (E, THETA, IOPT)

E - Electron kinetic energy (keV)

THETA - Incident angle (for IOPT = 2)

Called By: BKSCAT

ELFLUX

Purpose: Calculates incident electron flux and flux of electron-produced secondaries using subroutine ELSEC.

Calling Sequence: SUBROUTINE ELFLUX (ICELL, ITYPE, FIN, FOUT)

ICELL - Current surface cell

FIN - Incident electron flux (output)

FOUT - Flux of secondary electrons (output)

ITYPE - NASCAP operating mode

Called By: CALFLX

ELSEC

Purpose: Calculates secondary yield for electrons of energy E (keV) which are normally incident (IOPT=1) incident at angle THETA (IOPT=2), or isotropically incident (IOPT=4). Subroutine ELSEC1 is identical to ELSEC.

Calling Sequence: SUBROUTINE ELSEC (YIELD, E, THETA, IOPT)

Called By: ELFLUX

IOFLX

Purpose: Output of fluxes, potentials and fields across dielectrics for selected surface cells.

Calling Sequence: SUBROUTINE IOFLX (EIN, EOUT, PIN, POUT, EBACK, PCUR, PCND, ICELL)

Called By: CALFLX

PRFLUX

Purpose: Calculates flux of incident protons and resulting secondaries using subroutine PROSEC.

Calling Sequence: SUBROUTINE PRFLUX (ICELL, ITYPE, FIN, FOUT)

Called By: CALFLX

PROSEC

Purpose: Calculates secondary electron yield for incident protons of energy E (keV), incidence may be normal (IOPT=1), isotropic (IOPT=4) or at angle THETA (IOPT=2).

Calling Sequence: SUBROUTINE PROSEC (YIELD, E, THETA, IOPT)

Called By: PRFLUX

SOLFLX

Purpose: Calculates flux of photoelectrons from surface cell using material properties and shadowing calculation output.

Calling Sequence: SUBROUTINE SOLFLX (ICELL, PCUR)

Called By: CALFLX

8.5 FORCE CALCULATION, VECTOR MANIPULATION AND INFORMATION DECODING ROUTINES

ADDVXB

Purpose: Computes vector product

$$\overrightarrow{VOUT} = \overrightarrow{VIN} + CMAG*\overrightarrow{VIN} \times \vec{B}$$

Calling Sequence: SUBROUTINE ADDVXB (VOUT, VIN, B, CMAG)

Called By: PUSH, PHOCUR, ETNGUN

BFIELD

Purpose: Computes magnetic field (in W/m^2) $\vec{B}$ at point $\vec{X}$.

Calling Sequence: SUBROUTINE BFIELD (B, X)

Called By: PUSH, PHOCUR, ETNGUN, MAGCMP

EFIELD

Purpose: Compute the local electric field components for a plasma particle and determine whether the particle has collided with the object or exited the outermost grid.

Calling Sequence: EFIELD (E, X, ITEST)

Input X(3) is the particle position.

Output E(3) is the vector electric field

$$\text{ITEST} = \begin{cases} 0 & \text{particle in free space} \\ 1 & \text{particle is outside the second mesh} \\ -1 & \text{particle inside the object} \end{cases}$$

Called By: PUSH, PHOCUR and ETNGUN. (A flowchart of EFIELD is included in the description of subroutine PUSH, Figure 8.3.)

Method: EFIELD calls the following subroutines:

LCODE - decodes the element table for cells that are partially full.

TRAND - transforms the fractional particle position inside a special cell to the standard orientation of that cell (e.g., from $10\bar{1}$ to 110 for wedges).

INSID1 - determines (using the transformed particle position) whether the particle is inside or outside the object.

TRANA - transforms the matrix of eight potentials of a special cell to the standard orientation of that type of cell.

ESPEC - actually calculates all the electric fields. This is done in the appropriate standard orientation for special cells.

TRANE - transforms the special cell electric field vector from the standard orientation back to the orientation of the particular element that the particle is in.

ESPEC

Purpose: Calculates local electric field in a zone in the standard orientation. (See Figures 6.19 to 6.24.)

Calling Sequence: ESPEC (E, X, P, ITYP)

Input X(3) position in cell.

P(8) potential at the eight vertices of the cell (for some cells not all the potentials are used).

ITYP (cell type)
= 0 cube (empty cell)
= 1 wedge (110)
= 2 cube with line on z face
= 3 tetrahedron (111)
= 4 truncated cube (111)

Output E(3) local electric field

Called By:

Method: Uses analytical derivative of the trilinear (cube), bilinear (wedge) or linear (tetrahedron) basis sets. The formulation for the truncated cube is only approximate and uses trilinear weights with an extrapolated potential at the missing vertex.

FILINP

Purpose: Fills in the boundary region of the outer grid with values from the inner grid.

Calling Sequence: SUBROUTINE FILINP (P1, P2, NX, NY, NZ, NG)

Called By: TRILIN, CHARGE

GETCEL

Purpose: Places geometrical and electrostatic properties of surface cell in common block SRFPRM.

Calling Sequence: SUBROUTINE GETCEL (ICELL, PCOND)

Called By: CALFLX, SHECAL

INSID1

Purpose: Determines whether transformed point $\overrightarrow{DX}$ is interior given cell of type ITYP in standard orientation.

Calling Sequence: FUNCTION INSID1 (DX, ITYP)

Called By: EFIELD

LCODE

Purpose: Decodes entry in LTBL (volume cell element table). (See EFIELD.)

Calling Sequence: SUBROUTINE LCODE

L	- Element table entry
ITYP	- Cell type
IOR(3)	- Orientation code
JCURCL	- Index entered by NUMLTB

Called By: EFIELD

TRANA

Purpose: Rearranges the eight vertices of a cube AI(2,2,2) into AJ(2,2,2) by the same transformation of axes that transform vector I(3) into J(3).

Calling Sequence: SUBROUTINE TRANA (AI, AJ, I, J)

Called By: EFIELD

TRAND

Purpose: Transforms real positive differential displacement vector DI(3) into DJ(3) as vector I(3) is transformed into J(3). All components of DJ are positive and less than unity.

Calling Sequence: SUBROUTINE TRAND (DI, DJ, I, J)

Called By: EFIELD

TRANE

Purpose: Transforms electric field vector EI(3) into EJ(3) as vector I(3) goes to J(3).

Calling Sequence: SUBROUTINE TRANE (EI, EJ, I, J)

Called By: EFIELD

TRAAN

Purpose: Takes a rotation matrix AI and transforms it into AJ by the same axis interchanges that converted vector I(3) to J(3). It determines the interchanges as well as transforms the matrix.

Calling Sequence: SUBROUTINE TRAAN (AI, AJ, I, J)

Called By: PUSH

VADD

Purpose: Add two 3 vectors: $\vec{A} = \vec{B} + \vec{C}$.

Calling Sequence: SUBROUTINE VADD (A, B, C)

Called By: Various routines

VADDS

Purpose: Add two 3 vectors after multiplying one by a scalar: $\vec{A} = \vec{B}$ + SCALAR x $\vec{C}$.

Calling Sequence: SUBROUTINE VMULT (Y, A, X)

Called By: Various routines

VMULT

Purpose: Multiply a three vector, X, by a 3 x 3 matrix A, and yield result Y: $\vec{Y} = \underset{\approx}{A}\vec{X}$.

Calling Sequence: SUBROUTINE VMULT (Y, A, X)

Called By: Various routines

VSET

Purpose: Set 3 vector A equal to 3 vector B: $\vec{A} = \vec{B}$.

Calling Sequence: SUBROUTINE VSET (A, B)

Called By: Various routines

8.6 PHOTOSHEATH ROUTINES

PHOCUR

Purpose: Photoelectron and secondary electron contributions to space charge densities and to surface currents for a given zone are calculated in this routine by following test particles forward in time. The particles are pushed in a fashion entirely analogous to PUSH. If particles are within one zone of a surface cell, all three components of the current are stored. This is used to define local particle fluxes.

Calling Sequence: SUBROUTINE PHOCUR (PHOJ, QEMIT)

Called By: SHECAL

Local Variables: XO(3): Center of cell
XI(3,4): Places where test particles are emitted

SHECAL

Purpose: Performs logical functions and charge sharing for photosheath calculations. (See flow chart, Figure 8.4.)

Calling Sequence: SUBROUTINE SHECAL (PHOJ, FLOW, FLUXES, PCOND)

PHOJ(3,1024) - Array for fluxes in selected volume cells
FLOW - Low energy electron flux emitted from each surface cell
FLUXES - Net flux to each surface cell
PCOND - Conductor potential array

Called By: CHARGE

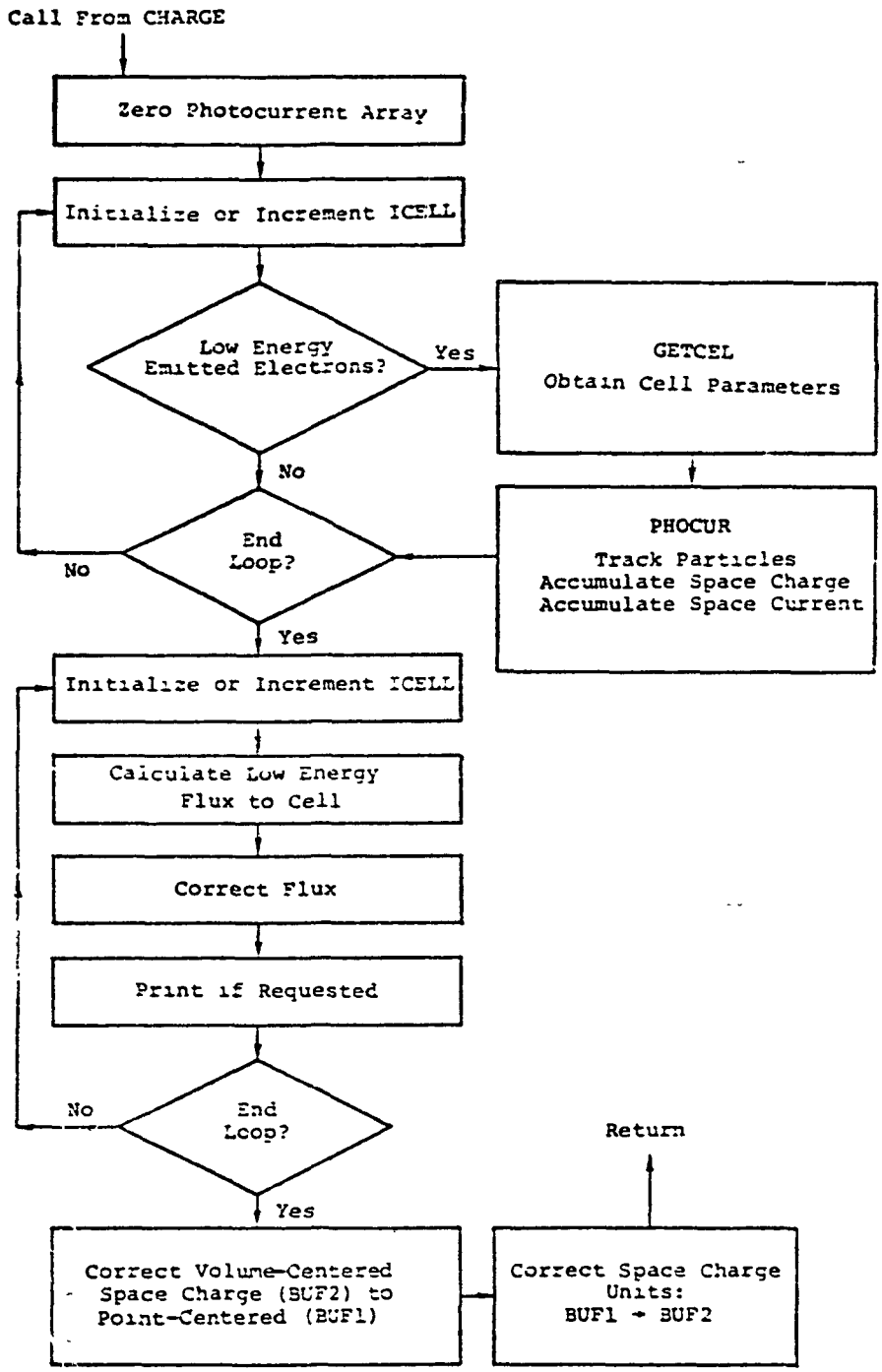


Figure 8.4. Photosheath calculation (SHECAL) flow chart.

9. CODE DESCRIPTION — SATPLT, HIDCEL AND OTHER GRAPHICS SECTIONS

SATPLT calls all routines responsible for satellite illustration plots. HIDCEL creates three-dimensional perspective plots, while MATPLT produces the shaded area silhouettes. CONPLT plots potential contours, ROUSP plots ROUS charge contours, and PARPLT plots particle trajectories.

Only the three-dimensional hidden-line plots are complex enough to warrant an algorithm description. Following is a description of the HIDCEL algorithm and documentation of all plot-related subroutines.

9.1 SHADOWING ALGORITHM DESCRIPTION

For purposes such as calculating photoemission effects it is desirable to be able to calculate the shadowing effects of the satellite upon itself for an arbitrary angle of incident sunlight. A subroutine called HIDCEL computes for each surface grid cell the area of that part of the cell which remains exposed when partially or completely shadowed by some other portion of the satellite (or, of course, when not shadowed at all). The program is completely general: For any satellite which NASCAP can treat, any incident angle may be specified as a vector from the center of the satellite out towards the viewer (sun). In addition to calculating the cell-by-cell areas needed for code computations, HIDCEL plots a diagnostic (and informative) hidden line 3-D plot of the satellite as viewed from the incident angle requested.

The code accomplishes both the area calculations and 3-D plots by a long series of polygon maskings. The set of cell faces whose normals produce positive dot products with the vector pointing towards the viewer are selected and projected into 2-D polygons. We call this set of individual cell polygons the A1 polygons. A second but much shorter set of polygons is selected and projected into 2-D by finding those faces of each parallelepiped, wedge, tetrahedron, octagon, etc. forming the satellite (as determined by user input), which meet the dot product criterion. We call this set the A2 polygons.

The cell-by-cell (A1) set of 2-D polygons is then masked one at a time against each of the larger "building-block" (A2) polygons, and at each step we discard any polygon which is partially or completely shielded and replace it, if necessary, with the polygon (or polygons) representing that part of the original cell which remains visible.

An A1 polygon which is completely shadowed, but is masked by several different surfaces, will then be "whittled down" a bit at a time, each masking leaving an appropriately smaller polygon until the last masking for that cell finally removes it from the system. A polygon whose middle is masked but whose ends remain visible will be split into two or more new polygons; the code maintains records, however, indicating which original cell has generated each new polygon. Consequently, when all maskings have been completed and a finalized set of masked A1 polygons exists, we may calculate areas of each polygon and add into the appropriate cell area the area of each polygon contributing to that cell.

The areas stored for further NASCAP calculations are fractional areas with the dot product (2-D projection) effect removed. We do this by calculating the areas of each cell's 2-D projection before any masking takes place and then computing the fraction of this area which remains visible following all maskings. This procedure also precludes any area normalization problems.

Figures 9.1 through 9.3 illustrate plot output of the shadowing program for several different angles of viewing. Figures 9.4 and 9.5 demonstrate printed output of the areas and fractional areas for one case.

As is evident, for a satellite of this complexity, we may be masking on the order of 500 cell faces against on the order of 150 building-block faces for a total of about 75,000 individual maskings. Computing time (including plot generation) on S^3's UNIVAC 1108 varies from 5 to 60 seconds per view, depending on satellite complexity.

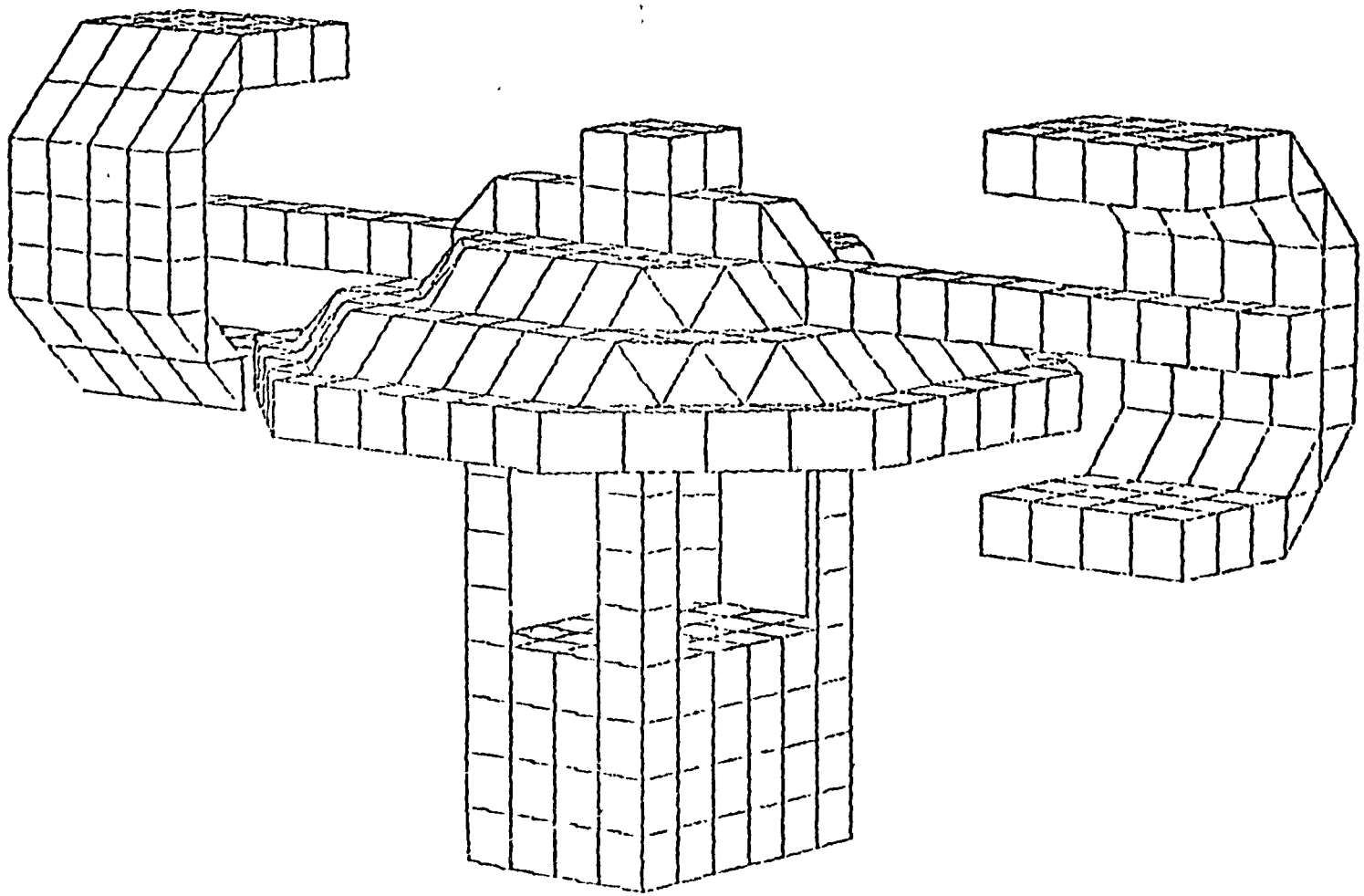


Figure 9.1. Plot output of shadowing routines.

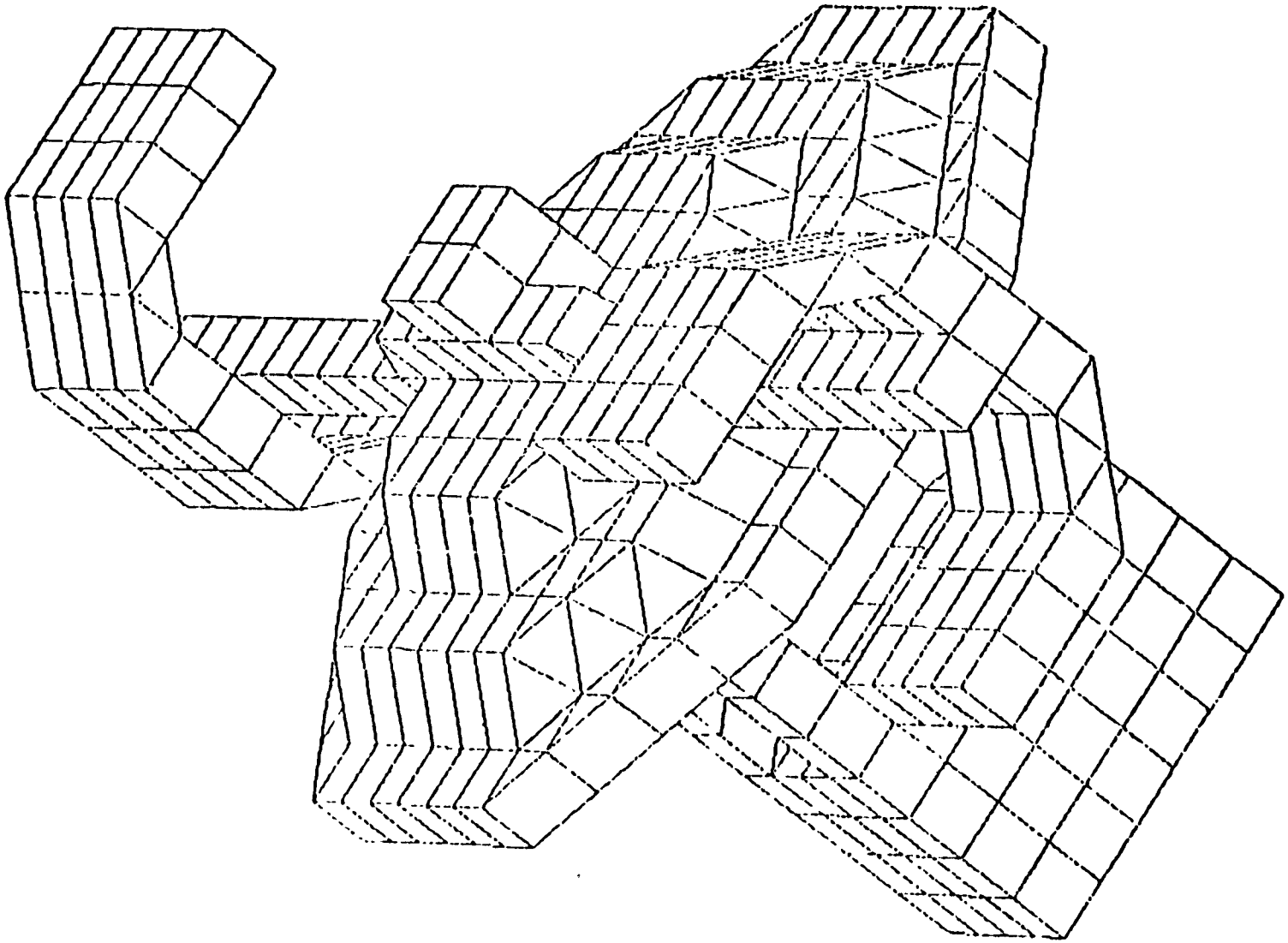


Figure 9.2. Plot output from shadowing routines.

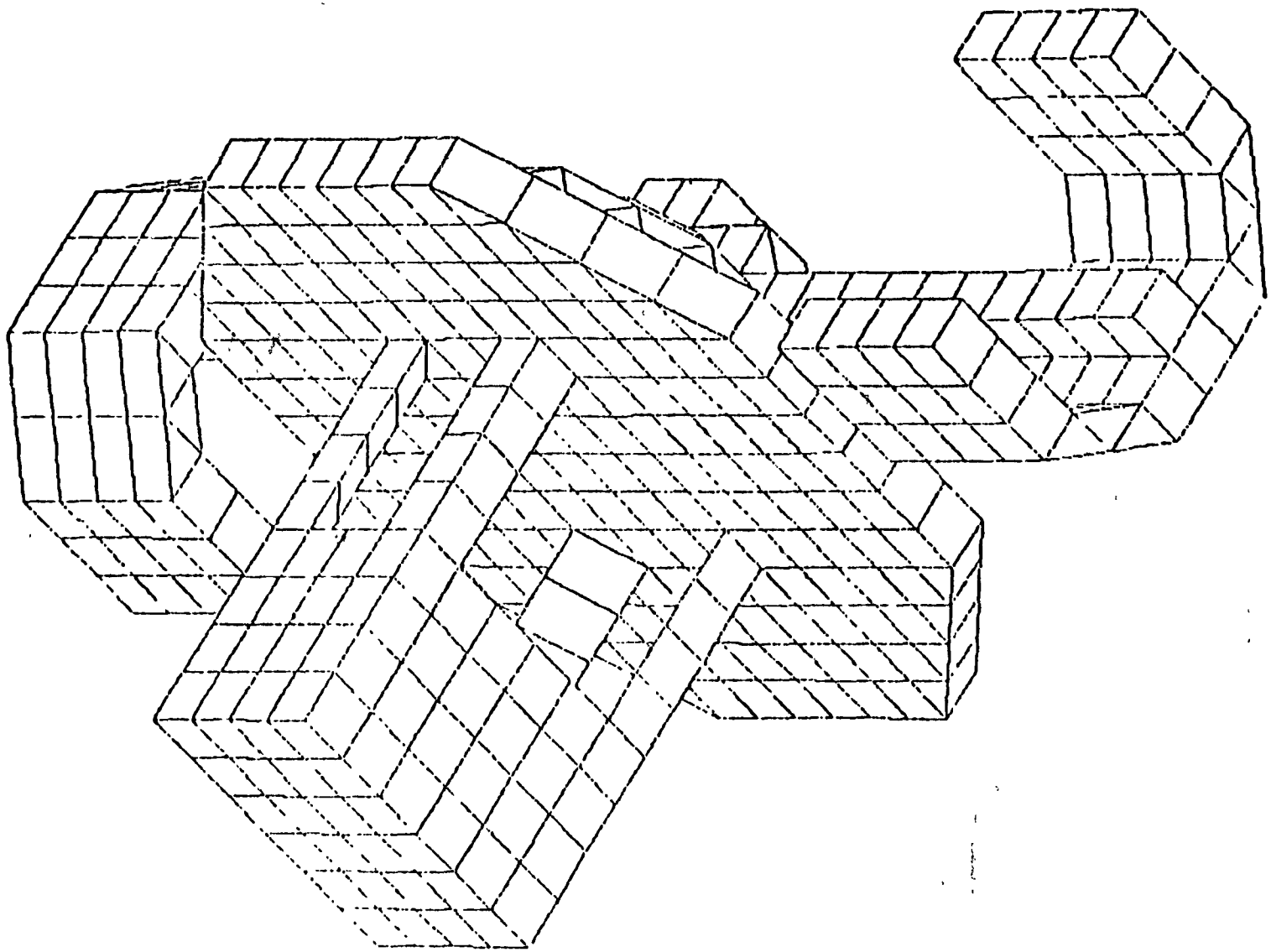


Figure 9.3. Plot output from shadowing routines.

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OF POOR QUALITY

```
POLYGON 13 FOR CELL 31 WITH 4 VERTICES WAS INITIAL AREA = 3.8642-01
POLYGON 14 FOR CELL 32 WITH 4 VERTICES WAS INITIAL AREA = 3.8732-01
POLYGON 15 FOR CELL 33 WITH 4 VERTICES WAS INITIAL AREA = 3.8823-01
POLYGON 16 FOR CELL 34 WITH 4 VERTICES WAS INITIAL AREA = 3.8913-01
POLYGON 17 FOR CELL 35 WITH 4 VERTICES WAS INITIAL AREA = 3.9005-01
POLYGON 18 FOR CELL 37 WITH 4 VERTICES WAS INITIAL AREA = 3.9096-01
POLYGON 19 FOR CELL 38 WITH 4 VERTICES WAS INITIAL AREA = 2.8298-01
POLYGON 20 FOR CELL 40 WITH 3 VERTICES WAS INITIAL AREA = 1.9591-01
POLYGON 21 FOR CELL 43 WITH 3 VERTICES WAS INITIAL AREA = 1.9182-01
POLYGON 22 FOR CELL 45 WITH 4 VERTICES WAS INITIAL AREA = 3.8429-01
POLYGON 23 FOR CELL 46 WITH 4 VERTICES WAS INITIAL AREA = 3.6516-01
POLYGON 24 FOR CELL 47 WITH 4 VERTICES WAS INITIAL AREA = 3.6608-01
POLYGON 25 FOR CELL 48 WITH 4 VERTICES WAS INITIAL AREA = 3.8698-01
POLYGON 26 FOR CELL 49 WITH 4 VERTICES WAS INITIAL AREA = 3.8789-01
POLYGON 27 FOR CELL 50 WITH 4 VERTICES WAS INITIAL AREA = 3.8879-01
POLYGON 28 FOR CELL 51 WITH 4 VERTICES WAS INITIAL AREA = 3.8970-01
POLYGON 29 FOR CELL 52 WITH 4 VERTICES WAS INITIAL AREA = 3.9062-01
POLYGON 30 FOR CELL 53 WITH 4 VERTICES WAS INITIAL AREA = 3.9153-01
POLYGON 31 FOR CELL 55 WITH 4 VERTICES WAS INITIAL AREA = 3.9245-01
POLYGON 32 FOR CELL 56 WITH 4 VERTICES WAS INITIAL AREA = 2.8406-01
POLYGON 33 FOR CELL 58 WITH 3 VERTICES WAS INITIAL AREA = 1.9666-01
POLYGON 34 FOR CELL 61 WITH 3 VERTICES WAS INITIAL AREA = 1.9165-01
POLYGON 35 FOR CELL 63 WITH 4 VERTICES WAS INITIAL AREA = 3.8395-01
POLYGON 36 FOR CELL 64 WITH 4 VERTICES WAS INITIAL AREA = 3.8465-01
POLYGON 37 FOR CELL 65 WITH 4 VERTICES WAS INITIAL AREA = 3.8574-01
POLYGON 38 FOR CELL 66 WITH 4 VERTICES WAS INITIAL AREA = 3.8664-01
POLYGON 39 FOR CELL 67 WITH 4 VERTICES WAS INITIAL AREA = 3.8755-01
POLYGON 40 FOR CELL 68 WITH 4 VERTICES WAS INITIAL AREA = 3.8845-01
POLYGON 41 FOR CELL 69 WITH 4 VERTICES WAS INITIAL AREA = 3.8936-01
POLYGON 42 FOR CELL 70 WITH 4 VERTICES WAS INITIAL AREA = 3.9027-01
POLYGON 43 FOR CELL 71 WITH 4 VERTICES WAS INITIAL AREA = 3.9119-01
POLYGON 44 FOR CELL 72 WITH 4 VERTICES WAS INITIAL AREA = 3.9211-01
POLYGON 45 FOR CELL 73 WITH 4 VERTICES WAS INITIAL AREA = 3.9303-01
POLYGON 46 FOR CELL 75 WITH 4 VERTICES WAS INITIAL AREA = 3.9395-01
POLYGON 47 FOR CELL 76 WITH 4 VERTICES WAS INITIAL AREA = 2.8514-01
POLYGON 48 FOR CELL 78 WITH 3 VERTICES WAS INITIAL AREA = 1.9741-01
POLYGON 49 FOR CELL 81 WITH 4 VERTICES WAS INITIAL AREA = 3.8362-01
POLYGON 50 FOR CELL 82 WITH 4 VERTICES WAS INITIAL AREA = 3.8451-01
POLYGON 51 FOR CELL 83 WITH 4 VERTICES WAS INITIAL AREA = 3.8541-01
POLYGON 52 FOR CELL 84 WITH 4 VERTICES WAS INITIAL AREA = 3.8631-01
POLYGON 53 FOR CELL 85 WITH 4 VERTICES WAS INITIAL AREA = 3.8721-01
POLYGON 54 FOR CELL 86 WITH 3 VERTICES WAS INITIAL AREA = 1.9418-01
POLYGON 55 FOR CELL 87 WITH 4 VERTICES WAS INITIAL AREA = 3.8902-01
POLYGON 56 FOR CELL 88 WITH 4 VERTICES WAS INITIAL AREA = 3.8993-01
POLYGON 57 FOR CELL 89 WITH 3 VERTICES WAS INITIAL AREA = 1.9539-01
POLYGON 58 FOR CELL 90 WITH 4 VERTICES WAS INITIAL AREA = 3.9176-01
POLYGON 59 FOR CELL 91 WITH 4 VERTICES WAS INITIAL AREA = 3.9268-01
POLYGON 60 FOR CELL 92 WITH 4 VERTICES WAS INITIAL AREA = 3.9360-01
POLYGON 61 FOR CELL 93 WITH 4 VERTICES WAS INITIAL AREA = 3.9453-01
POLYGON 62 FOR CELL 94 WITH 4 VERTICES WAS INITIAL AREA = 7.3228-01
POLYGON 63 FOR CELL 96 WITH 4 VERTICES WAS INITIAL AREA = 3.9546-01
POLYGON 64 FOR CELL 99 WITH 4 VERTICES WAS INITIAL AREA = 3.3417-01
POLYGON 65 FOR CELL 100 WITH 4 VERTICES WAS INITIAL AREA = 3.3507-01
POLYGON 66 FOR CELL 101 WITH 4 VERTICES WAS INITIAL AREA = 3.0597-01
```

Figure 9.4. Printed output from shadowing routines.

```
FINAL NAI =    430
    IAI =     1  NV =  5  IAIT =  108  AREAI(IAIT) =  3.9234-01
    IAI =     2  NV =  4  IAIT =   89  AREAI(IAIT) =  1.2296-01
    IAI =     3  NV =  5  IAIT =    9  AREAI(IAIT) =  3.8586-01
    IAI =     4  NV =  5  IAIT =   12  AREAI(IAIT) =  3.6676-01
    IAI =     5  NV =  5  IAIT =   15  AREAI(IAIT) =  3.8766-01
    IAI =     6  NV =  5  IAIT =   18  AREAI(IAIT) =  3.8857-01
    IAI =     7  NV =  5  IAIT =   21  AREAI(IAIT) =  3.8948-01
    IAI =     8  NV =  5  IAIT =   22  AREAI(IAIT) =  2.8190-01
    IAI =     9  NV =  4  IAIT =   24  AREAI(IAIT) =  1.9517-01
    IAI =    10  NV =  6  IAIT =   88  AREAI(IAIT) =  3.4731-01
    IAI =    11  NV =  5  IAIT =   70  AREAI(IAIT) =  2.6724-01
    IAI =    12  NV =  4  IAIT =   49  AREAI(IAIT) =  2.0647-02
CELL    69 GETTING ADDITIONAL CONTRIBUTION FROM POLYGON  13
    IAI =    13  NV =  4  IAIT =   49  AREAI(IAIT) =  6.2823-02
    IAI =    14  NV =  5  IAIT =   32  AREAI(IAIT) =  3.8732-01
    IAI =    15  NV =  5  IAIT =   33  AREAI(IAIT) =  3.8823-01
    IAI =    16  NV =  5  IAIT =   34  AREAI(IAIT) =  3.8913-01
    IAI =    17  NV =  5  IAIT =   35  AREAI(IAIT) =  3.9005-01
    IAI =    18  NV =  5  IAIT =   96  AREAI(IAIT) =  3.9546-01
    IAI =    19  NV =  5  IAIT =   38  AREAI(IAIT) =  2.8298-01
    IAI =    20  NV =  4  IAIT =   40  AREAI(IAIT) =  1.9591-01
    IAI =    21  NV =  6  IAIT =   27  AREAI(IAIT) =  1.3679-01
    IAI =    22  NV =  5  IAIT =  104  AREAI(IAIT) =  3.8868-01
    IAI =    23  NV =  5  IAIT =   87  AREAI(IAIT) =  3.8902-01
    IAI =    24  NV =  5  IAIT =   48  AREAI(IAIT) =  2.2257-01
    IAI =    25  NV =  4  IAIT =   85  AREAI(IAIT) =  1.2119-01
    IAI =    26  NV =  6  IAIT =   50  AREAI(IAIT) =  3.6781-01
    IAI =    27  NV =  5  IAIT =   49  AREAI(IAIT) =  1.6440-01
    IAI =    28  NV =  5  IAIT =   51  AREAI(IAIT) =  3.8970-01
    IAI =    29  NV =  5  IAIT =   52  AREAI(IAIT) =  3.9062-01
    IAI =    30  NV =  5  IAIT =   53  AREAI(IAIT) =  3.9153-01
    IAI =    31  NV =  5  IAIT =   75  AREAI(IAIT) =  3.9395-01
    IAI =    32  NV =  5  IAIT =   56  AREAI(IAIT) =  2.8406-01
    IAI =    33  NV =  4  IAIT =   58  AREAI(IAIT) =  1.9666-01
    IAI =    34  NV =  6  IAIT =  716  AREAI(IAIT) =  3.7951-01
    IAI =    35  NV =  6  IAIT =   44  AREAI(IAIT) =  3.4313-01
    IAI =    36  NV =  7  IAIT =   47  AREAI(IAIT) =  2.9426-01
    IAI =    37  NV =  4  IAIT =   46  AREAI(IAIT) =  4.2595-02
    IAI =    38  NV =  4  IAIT =   45  AREAI(IAIT) =  1.9549-02
    IAI =    39  NV =  4  IAIT =   48  AREAI(IAIT) =  8.2098-02
CELL    48 GETTING ADDITIONAL CONTRIBUTION FROM POLYGON  40
    IAI =    40  NV =  4  IAIT =   48  AREAI(IAIT) =  8.5721-02
    IAI =    41  NV =  5  IAIT =   44  AREAI(IAIT) =  2.1741-01
    IAI =    42  NV =  6  IAIT =   3.  AREAI(IAIT) =  3.0297-01
    IAI =    43  NV =  5  IAIT =   71  AREAI(IAIT) =  3.9119-01
    IAI =    44  NV =  5  IAIT =   72  AREAI(IAIT) =  3.9211-01
    IAI =    45  NV =  5  IAIT =   73  AREAI(IAIT) =  3.9303-01
    IAI =    46  NV =  5  IAIT =   55  AREAI(IAIT) =  3.9245-01
```

Figure 9.5. Printed output from shadowing routines.

```
 5   -3.25817147     4.34194607
IA1 =  398     IAIT =  514     NV =  5
 1   -3.74594757     3.84861889     2   -3.75301361     3.23750311     3   -3.76399779     3.22684256     4   -4.53302056     3.70681837
 5   -3.74594757     3.84861889
IA1 =  399     IAIT =  869     NV =  5
 1   -1.73398747    10.92237055     2   -2.36569330    10.31210470     3   -3.15301472    10.80036557     4   -2.52117002    11.41015085
 5   -1.73398747    10.92237055
IA1 =  400     IAIT =  874     NV =  6
 1   -1.57775089     9.82345867     2   -1.42123684     8.72259498     3   -1.49997807     8.64637244     4   -1.57650746     9.18492627
 5   -1.57775089     9.82345867
IA1 =  401     IAIT =  778     NV =  5
 1   -5.24288136    -6.35051447     2   -5.24692601    -6.73794442     3   -5.09702837    -6.82820654     4   -5.09309584    -7.44044712
 5   -5.24288136    -6.35051447
IA1 =  402     IAIT =  779     NV =  6
 1   -5.17946702    -5.64430523     2   -5.10096699    -6.21499997     3   -5.09702837    -6.82820654     4   -5.24692601    -5.73794442
 5   -5.24782819    -5.60130417     4   -5.17946702    -5.64430523
IA1 =  403     IAIT =  842     NV =  5
 1   -2.36569330    10.31210470     2   -1.73398747    10.92237055     3   -.94618420     10.43420569     4   -1.57775091     9.82345879
 5   -2.36569330    10.31210470
IA1 =  404     IAIT =  264     NV =  4
 1   -5.18154585    -1.91540562     2   -4.55482036    -.67442122     3   -4.65124688    -1.30183706     4   -5.18154585    -1.91540562
IA1 =  405     IAIT =  237     NV =  5
 1   -4.55482036    -.67442122     2   -4.55124688    -1.30183706     3   -3.92156677    -.68887006     4   -3.92464337    -.06126095
 5   -4.55482036    -.67442122
IA1 =  406     IAIT =  872     NV =  4
 1   -1.57531671     8.57344317     2   -1.57650746     9.18492603     3   -1.49997807     8.64637244     4   -1.57531671     8.57344329
IA1 =  407     IAIT =  838     NV =  5
 1   -.63141165     7.59459835     2   -.63191030     8.23269427     3   -1.26444453     7.61977410     4   -1.26344632     6.98184729
 5   -.63141165     7.59459841
IA1 =  408     IAIT =  164     NV =  5
 1   -1.42095592     4.52986586     2   -1.41342634     4.27602452     3   -2.04261798     3.66477269     4   -2.45021921     3.91886330
 5   -1.42095692     4.52986586
IA1 =  409     IAIT =  848     NV =  5
 1   -1.26344632     6.98184729     2   -1.26444453     7.61977410     3   -1.89760390     7.00624818     4   -1.89610510     6.36849117
 5   -1.26344632     6.98184729
IA1 =  410     IAIT =  873     NV =  4
 1   -.78918665     9.33442724     2   -1.57775091     9.82345879     3   -1.42123684     8.72259498     4   -.78918665     9.33442724
IA1 =  411     IAIT =  148     NV =  5
 1   -1.19230959     6.14026934     2   -.78486172     4.88667691     3   -1.41342634     4.27602452     4   -1.82076590     4.52986586
 5   -1.19230959     6.14026934
IA1 =  412     IAIT =  130     NV =  4
 1   -.63000214     5.79094571     2   -.15689352     5.49673045     3   -.78466172     4.88667691     4   -1.19230959     6.14026934
 5   -.42992042     5.68633848     4   -.63000214     5.79094571
IA1 =  413     IAIT =  843     NV =  5
 1   -1.57775089     9.82345879     2   -2.36569330    10.31210470     3   -2.36382944     9.67343891     4   -1.57650746     9.18492603
 5   -1.57775089     9.82345879
IA1 =  414     IAIT =  827     NV =  4
 1   -1.42123684     8.72259496     2   -.63191030     8.23269427     3   -.78918665     9.33442724     4   -1.42123684     8.72259496
IA1 =  415     IAIT =  862     NV =  5
 1   -1.49610510     6.36849117     2   -1.89760390     7.00624818     3   -2.53138927     6.39211571     4   -2.52938873     5.75452888
 5   -1.49610510     6.36849117
IA1 =  416     IAIT =  860     NV =  5
 1   -2.52938873     5.75452882     2   -2.53134927     6.39211571     3   -3.32113504     6.88347018     4   -3.31851146     6.24574703
 5   -2.52938873     5.75452888
```

Figure 9.5. Continued.

9.2 SUBROUTINE DESCRIPTIONS

ADDA1

Calling Sequence: SUBROUTINE ADDA1 (A3, N3, A1, NA1, NV1, IFFS, IFF1, A1RS, A1R, A1BS, A1FS, A1B, A1F, XMIN1, XMAX1, YMIN1, YMAX1, IA1)

Called By: HIDCEL

Purpose: ADDA1 adds a new polygon and its associated information to the end of the A1 polygon list.

AREA

Calling Sequence: FUNCTION AREA (A, N)

Called By: HIDCEL, FINVER

Local Variables: A(2,N): Vertices of a 2-D polygon

N: Number of vertices

Purpose: AREA's value is the area of polygon A.

A1COMP

Calling Sequence: SUBROUTINE A1COMP (A1, NA1, NV1, IFF1, A1R, A1B, A1F, XMIN1, XMAX1, YMIN1, YMAX1, IREMOV)

Called By: HIDCEL

Purpose: A1COMP is called following masking of all A1 polygons against one A2 polygon. A1COMP removes all flagged A1 polygons (any which have been partially or wholly shielded), and compresses the list by inserting polygons from the end of the list into those spaces occupied by the removed ones.

A1GEN

Calling Sequence: SUBROUTINE A1GEN (DIR, A1, A1B, A1F, NA1, NV1, DV1, A1R, IFF1, XMIN1, XMAX1, YMIN1, YMAX1, NSURF, JSURF, IP)

Called By: HIDCEL

Purpose: A1GEN generates the vertices in 3-D of all A1 individual cell faces whose normals have positive dot product with the direction of viewing. Each of these 3-D polygons is then projected into 2-D by calling PRSPPJ. The final set of 2-D vertices is stored in the A1 array. In addition, 2-D XMIN's, XMAX's, YMIN's, and YMAX's are calculated and stored for use in rough masking and behindness tests.

A2GEN

Calling Sequence: SUBROUTINE A2GEN (DIR, A2, A2B, A2F, IFAC, NA2, IFF2, DV2, A2R, NV2, NBLK, NPBLK, IPER, XMIN2, XMAX2, YMIN2, YMAX2, IP)

Called By: HIDCEL

Purpose: A2GEN generates the 3-D and 2-D projected coordinates for the "building-block" face A2 surfaces whose normals have a positive dot product with the direction of viewing. A2GEN also computes and saves minima and maxima for use in behindness tests.

Internal Organization: We start with a loop over all building-blocks making up the satellite as defined by user input to OBJDEF. The number of points in the block (NPBLK(IBLK)) tells us which type block it is of the five possible types: rectangular, parallelepiped, wedge, octagon, or "FIL111" type. From the type, we know how many faces this block has, and we loop over each face for the current block.

Using face normal data stored in the IFAC array (see SETFAC), we find the normal for the current face and place it in IFF(3). We compute the dot product of this face normal with the direction of viewing, and skip this face if its dot product is less than or equal to 1.E-10.

If we keep this face we must find its 3-D vertices. We pick the vertices for this face in order out of array IPER according to the face index, the type of block, and the vertex index data stored in IV (see SETFAC).

Next, we project the 3-D vertex set into 2-D by calling PRSPPJ for each vertex. We also store the distance to the viewer for each vertex in DV2. The closest and

furthest points to the viewer are found and stored in A2F and A2B. The 2-D minima and maxima are calculated and stored, and the first vertex is appended to the vertex list.

All faces of all blocks are looped through in this manner.

A2PLOT

Calling Sequence: SUBROUTINE A2PLOT (NBLK, NPBLK, IPER, A2P)

Called By: HIDCEL

Purpose: A2PLOT plots the non-hidden line plots of the building-block faces when HIDCEL is called with IAREA = 1. If drastic errors have been made in defining the building blocks which make up the satellite, A2PLOT plots will reveal them in an obvious manner.

CONPLT

Calling Sequence: SUBROUTINE CONPLT (IXYZ, IND, NX, NY, NZ, P1, P2, IPER, PER, IOBPLT)

Called By: TRILIN

Local Variables: IXYZ: IXYZ = 1, 2 or 3 specifies contours through a fixed x, y or z plane

IND: Fixed value of x, y or z; index in next-to-inner grid at which cut is to be taken

P1: Inner grid potentials

P2: Next-to-inner grid potentials

Purpose: CONPLT plots potential contours for the inner two grids. The 3-D plane at which the potentials are plotted is specified by a fixed x, y or z. IXYZ determines which dimension is fixed, and IND is the fixed value.

IND is an index in the outer grid of the pair.

Internal Organization: CONPLT fills in a two-dimensional array P with the potential values at the specified cut. P has the fineness of the inner grid, but encompasses both grids. Potential values at the new finer points in the outer grid area of P are found by linear interpolation, while the values for the inner grid are simply those already present in P1.

CONTOR is called to plot the potential contours and titles.

The satellite silhouette is plotted by reading in the building-block data from file IPLT = IABS(IOBPLT) and plotting the block perimeters in IPER = PER projected into the appropriate plane and translated according to the new coordinate system.

CONPOT

Calling Sequence: SUBROUTINE CONPOT (BUF1, NX, NY, NZ, PCOND)

Called By: TRILIN

Purpose: CONPOT sets the potentials at points in the interior of the satellite (otherwise untreated) equal to the potential on conductor one.

FINVER

Calling Sequence: SUBROUTINE FINVER (INEW, NEW, A3, A2, N2, N3, N3INT, NA2SG3, IA2SG3, INS2, IN2, NJOIN, IJOIN, IP)

Called By: SHIELD

Local Variables:

INEW:	Number of points currently in the new polygon
NEW:	Index of new polygon being considered
N2:	Number of vertices in the current A2 polygon
N3(12):	Number of vertices (final) in each of the new polygons
N3INT(12):	Number of intersection points for each of the new polygons
NA2SG3(2,12):	Number of A2 segments intersected by up to two intersection points per new polygon, for up to twelve new polygons
IA2SG3(2,2,12):	Indices of A2 segments intersected for the intersection points indexed by NA2SG3
INS2(9):	INS2(I) is 0 or 1 if the Ith vertex of A2 is outside or inside A1
IN2:	Number of A2 vertices inside A1
NJOIN:	Not used
IJOIN:	Not used
IP:	Print flag

Purpose: FINVER completes the vertex set of a new polygon consisting of 1 or more A1 vertices and two points where A1 intersects the A2 perimeter, by adding those A2 vertices which

fall between the two intersection points and which are inside the original A1 polygon.

Internal Organization: First we determine if the first and last points of the new polygon are the same. If they are not, we proceed to the normal loops of the routine. If they are, we check if INEW = 3. If so, we have two points different to the finer accuracy of the intersection routine, but the same to the coarser accuracy of PTCOMP. We keep the finer accuracy polygon and return. If INEW $\neq$ 3, we have a redundant last vertex and remove it to yield an already complete polygon. We return with this polygon.

If the two intersection points are on the same A2 segment, we are done already.

The normal section of the routine marches around the vertices of A2 between the two intersection points, first in one direction, and then, if necessary, in the other. It searches until it finds a complete set of A2 vertices between the two points which are all within A1. This is the set of points we need. If any point in the first direction is outside A1, we skip out and search in the other direction. If no such set is found in the second direction, we error return.

For some very complex cases, we may need to calculate the area of the new polygon taken with each of the two possible vertex sets. The set providing the lesser area is the correct set.

HIDCEL

Calling Sequence: SUBROUTINE HIDCEL (PDIR, IPLOT, NX, NY, NZ, IAREA)

Called By: NASCAP, SATPLT

Local Variables: PDIR(3): Vector (not necessarily normalized) indicating direction from center of satellite to viewer (or sun, for shadowing).

Purpose: HIDCEL calls all routines associated with the 3-D plots. There are two modes of calling HIDCEL: (1) IAREA = 0 implies that this call is merely for satellite illustration, and both a "building-block" non-hidden line plot and a cell-by-cell hidden line plot will be plotted. In this case, no areas will be calculated; (2) IAREA $\neq$ 0 implies that this call is to generate hidden-cell fractional areas for each of the (up to 1024) surface cells. These areas will be written onto unit IAREA at the end of HIDCEL. A cell-by-cell hidden line plot is also plotted in this case, but no building-block plot is generated.

Internal Organization: HIDCEL first normalizes the PDIR(3) vector pointing from the center of the satellite towards the viewer. The normalized data is placed in DIR(3). PPJSET is then called to set up the 3-D to 2-D (PRSPPJ calls) and 2-D to 3-D (PRSPPK calls) conversion matrices. Data is read in from file IPLOT = IABS(IOBPLT) holding the building-block information which defines the satellite. If we are in mode IAREA = 0, subroutine A2PLOT is called to generate the 3-D non-hidden-line plot of the building blocks.

Next, A2GEN is called to generate all A2 polygons and all data associated with them. The set of A2 polygons is the set of building-block faces whose normals have a positive dot product with DIR, projected into the 2-D focal plane perpendicular to the direction of viewing as set up by PPJSET.

A1GEN is called to generate the set of A1 polygons and their associated data. The set of A1 polygons is the set of surface cell faces whose normals have a positive dot product with DIR, projected similarly into 2-D. The 2-D area of each A1 polygon is calculated and the information written onto file IAREA. These areas reflect the angle of a cell relative to the direction of view, and represent the entire 2-D area of each cell before shielding.

Two nested loops march through every combination of each A1 polygon with each A2 polygon. The outer loop loops through the A2 polygons. Thus, for one building-block face polygon, each cell face polygon is checked against it one at a time.

If the A2 vertex closest to the viewer is at least as far as the farthest A1 vertex, A2 is behind A1 and this combination is skipped.

2-D XMIN's, XMAX's, YMIN's, and YMAX's are generated in A1GEN and A2GEN for each A1 and A2 polygon. If A2's XMAX is greater than or equal to A1's XMIN, or if A2's XMIN is less than or equal to A1's XMAX, or similarly for the YMIN's and YMAX's, we skip this combination.

A variable called IMASK, initially set to 0, indicates whether we have yet determined if A1 is behind A2 and must be masked. If the A2 vertex furthest from the viewer is at least as close as the A1 vertex closest to the viewer, A1 is behind A2 and IMASK is set to 1. If IMASK is 0 at this point, however, several possibilities still exist as to whether the complex shielding algorithm must be executed for this combination (e.g., A1 may be <u>on</u> A2 in which case it must not be masked against A2). Subroutine SHIELD is called to make the final determination of whether masking is to be done, and to do it if so, or, if IMASK is already 1, to simply execute the shielding algorithm, skipping any further tests on behindness.

ISHLD is the main output indicator from SHIELD. ISHLD = -1 implies that no changes need be made in any of the polygon bookkeeping arrays. This occurs when it is determined that the polygons need not be masked against one another due to A1's being in front of or on A2, or when the polygons <u>are</u> masked against one another but there is no overlap. ISHLD $\geq$ 0 implies that the polygons were masked, that there is overlap, and that ISHLD <u>new</u> A1 polygons have been created and are currently in array A3 waiting to be transferred to array A1. Thus, if ISHLD = 0, the current A1 polygon was completely shielded by A2 and zero new polygons have been created. Regardless of whether any new polygons have been created or not, the current A1 polygon is flagged for removal by subroutine A1COMP by setting IREMOV(IA1) equal to 1.

If new polygons <u>have</u> been created (ISHLD $\geq$ 1), subroutine ADDA1 is called for each of them to add their respective information to the tail end of the A1 polygon arrays.

Next we loop back around to the beginning of the A1 polygon loop to begin checking of the next A1 polygon against the current A2 polygon.

When all A1 polygons (except those new ones created by comparison to the current A2 polygon) have been checked against the current A2 polygon, subroutine A1COMP compresses the arrays containing A1 polygon information by removing each polygon flagged in IREMOV, and replacing its data with data from the end of the list (starting with the last new A1 polygon created). Thus, when checking against the next A2 polygon begins, the list of A1 polygons which we check it against is exactly what we want it to be; the most current set of A1 polygons containing some already partially masked by previous A2's and containing no superfluous polygons.

When all A2 polygons have been checked against all A1 polygons, we are left with a final set of non-overlapping A1 polygons representing those parts of all surface cells remaining visible when viewed from direction DIR. We loop over this finalized set of A1 polygons calculating an overall 2-D XMIN, XMAX, YMIN and YMAX. We also calculate the area of each polygon and add it into the appropriate location in array AREA1. The index in AREA1 is the index of the original surface cell whose 2-D projection was the parent polygon of the current A1 polygon. This index is stored in bits 6-15 of IFF1(IA1). A given surface cell can generate two or more partially shielded new polygons if some thin part of the satellite crosses over the middle of the surface cell. For diagnostic purposes, a message to this effect is printed out along with the A1 polygon area whenever such a situation is encountered.

Next, the original unshielded areas of all surface cells are read back in from unit IAREA. (Cells which did not face the viewer have this area already set to zero and hence, in this sense, have already been shielded.) A second loop over the surface cells computes the fractional areas for each cell: final shielded 2-D area/initial unshielded 2-D area. In this way, the effect of the dot product on the area is removed.

Next, a user area for plotting is set up using the 2-D overall minima and maxima just calculated. A last loop over all final A1 polygons plots the perimeter of each polygon by simply connecting its vertices.

Finally, the IAREA file is rewound, the set of 1024 fractional areas is written onto it, and IAREA is rewound again for use by the rest of the code.

INSIDD

Calling Sequence: FUNCTION INSIDD (A, AD, P, PD, N, IP)

Called By: SHIELD

Local Variables: A(2,10): Single-precision polygon vertices

AD(2,10): Double-precision polygon vertices

P: Single-precision point

PD: Double-precision point

N: Number of vertices in polygon

IP: Print flag

Purpose: INSIDD determines if point P is inside polygon A. If P is on the perimeter of A, it is considered inside. INSIDD = 0 implies P is not inside A. INSIDD = 1 implies P is inside A.

INSIDD is used instead of INSIDE for determining if vertices of a polygon are inside the other and for resetting them to be exactly on the polygon perimeter if they are off by only some epsilon. This resetting is accomplished by calling PROLIN to do a double-precision calculation finding the projection of point P on the segment of A which it is almost on.

INSIDE

Calling Sequence: FUNCTION INSIDE (A, P, N, IP)

Called By: SHIELD

Local Variables: A(2,10): Vertices of a polygon

P(2): Point

N: Number of vertices of polygon

IP: Print flag

Purpose: INSIDE determines if point P is inside polygon A. If P is on the perimeter of A, it is considered inside. INSIDE = 0 implies P is not inside A. INSIDE = 1 implies P is inside A.

INSIDE is a single-precision function.

INTCHK

Calling Sequence: SUBROUTINE INTCHK (I1, A1, A1D, A2, A2D, INT, N2, INDINT, XINT, NA2SEG, IA2SEG, INS2, IP)

Called By: SHIELD

Local Variables:

I1:	Index of current A1 polygon segment
A1D:	Double-precision copy of A1
A2D:	Double-precision copy of A2
INT:	(output) number of intersections of segment I1 of A1 with A2 perimeter
N2:	Number of A2 segments
INDINT:	Not used
XINT(2,10):	(output) intersection points found
NA2SEG(10):	(output) number of A2 segments intersected by up to 10 intersection points
IA2SEG(2,10):	(output) indices of A2 segments intersected by up to 10 intersection points
INS2(9):	INS2(I) = 0 or 1 if vertex I of A2 is outside or inside A1
IP:	Print flag

Purpose: Given the I1th segment of A1, INTCHK checks for any and all intersections of this segment with all A2 segments. INTCHK also keeps track of which A2 segments are intersected, eliminates duplicate intersection points, and orders those kept according to how close to the start of the I1th A1 segment they are.

Internal Organization: INTCHK starts with a loop over the A2 segments. INTSEC is called to find any intersections of the A1 segment with the current A2 segment. If there were none, we go on to the next A2 segment. If there was one, we increment INT and record the A2 segment information in NA2SEG and IA2SEG (INTSEC has already placed the intersection point in XINT). The distance of this point to the start of the A1 segment is computed and stored in D for sorting purposes. If there has been at least one previous intersection, we check to see if we have a redundant intersection and eliminate it if so.

If the A1 segment does not "intersect" the A2 segment, but partially or wholly overlaps it, we do not need to count the intersection but we must record the A2 segment information in NA2SEG and IA2SEG for use by FINVER.

When all A2 segments have been checked, we sort all intersection points (if more than one) according to their distance from the start of A1, so that the closest ones will be treated first.

INTSEC

Calling Sequence: SUBROUTINE INTSEC (X1, X2, PXI, INTFLG, IP)

Called By: INTCHK

Local Variables:

X1(2,2):	First double-precision line segment
X2(2,2):	Second double-precision line segment
PXI(2):	(output) single-precision intersection of X1 and X2, if any
INTFLG:	(output) INTFLG = 0 implies no intersection; INTFLG = 1 implies an intersection; INTFLG = -1 implies the segments overlap.
IP:	Print flag

Purpose: INTSEC determines if segment X1 intersects segment X2, and if so, calculates the intersection in double-precision.

INTSEC finds the equations of the two lines, finds their intersection, and determines if that intersection is on both of the line segments by calling PTLINE.

LINPLN

Calling Sequence: SUBROUTINE LINPLN (XL1, DIR, XP, INB, XINT)

Called By: SHIELD

Local Variables: XL1(3): Start point of line

DIR(3): XL1 + DIR forms finish point of line

XP(3): Point on the plane

INB: Word containing bit-encoded normal to plane

Bits 0,1: x-component of normal

Bits 2,3: y-component of normal

Bits 4,5: z-component of normal

XINT(3): (output) intersection of the line with the plane

Purpose: LINPLN finds the intersection XINT of a 3-D line with a 3-D plane.

MATCAL

Calling Sequence: SUBROUTINE MATCAL (NX, NY, NZ, IOBPLT)

Called By: SATPLT

Purpose: MATCAL reads the satellite surface cell and material information from unit IOBPLT and calls MATPLT to plot the satellite material composition silhouettes.

MATPLT

Calling Sequence: SUBROUTINE MATPLT (NX, NY, NZ)

Called By: MATCAL

Purpose: MATPLT plots satellite silhouettes illustrating surface material composition via fifteen different shadings. The default mode is to plot six views from the plus or minus x, y and z directions, plotting all cells whose normal has a component in the direction of viewing. In cases where a cell face is partially or completely shielded by other cells in front of it, only the visible part of that cell (if any) is plotted and shaded. The sacrifice here is that inner surfaces hidden by outer surfaces may never be seen via the default views.

Hence, additional input allows the user to specify for any of the six basic viewing directions, additional plots showing only those cells within a specific range of x, y or z values according to the view involved.

MOVEA1

Calling Sequence: SUBROUTINE MOVEA1 (I1, I2, A1, NV1, IFF1, A1R, A1B, A1F, XMIN1, XMAX1, YMIN1, YMAX1)

Called By: A1COMP

Purpose: MOVEA1 moves the information for the I1th A1 polygon into the I2th position in all the A1 information arrays.

PARPLT

Calling Sequence: SUBROUTINE PARPLT (IXYZ, IPART, IOBPLT, NX, NY, NZ)

Called By: TRILIN

Local Variables: IXYZ: IXYZ = 1, 2 or 3 specifies particle trajectories projected onto the y-z, x-z or x-y plane (fixed x, fixed y or fixed z)

Purpose: PARPLT plots particle trajectories generated by subroutine PUSH projected onto either of the y-z, x-z or x-y planes. Separate plots are made for electrons and protons (species one and two).

The particle data is read from file IPART and plotted by connecting each successive location for one particle to the next.

The satellite silhouette is plotted by reading in the building-block data from file IPLT = IABS(IOBPLT), and plotting the block perimeters in IPER = PER projected onto the appropriate plane.

PROLIN

Calling Sequence: SUBROUTINE PROLIN (A, X, XP, IP)

Called By: INSIDD

Local Variables: A(2,2): Double-precision line segment

X(2): Double-precision point

XP(2): (output) projection of X on A

IP: Print flag

Purpose: PROLIN computes the projection XP of point X on line segment A.

PRSPPJ

Calling Sequence: Entry Point PPJSET: SUBROUTINE PPJSET (X1Q, X2Q, X3Q, X1V, X2V, X3V, D)

Entry Point PRSPPJ: SUBROUTINE PRSPPJ (X, Y, Z, XP, YP, ZP)

Entry Point PRSPPK: SUBROUTINE PRSPPK (XJ, YJ, ZJ, XI, YI, ZI)

Called By: HIDCEL (PPJSET)
A1GEN, A2GEN (PRSPPJ)
SHIELD (PRSPPJ, PRSPPK)

Local Variables:

X1Q:	x coordinate of satellite center (inner grid center)
X2Q:	y coordinate of satellite center (inner grid center)
X3Q:	z coordinate of satellite center (inner grid center)
X1V:	x coordinate of camera lens
X2V:	y coordinate of camera lens
X3V:	z coordinate of camera lens
D:	camera focal length
X:, Y:, Z:	coordinates of 3-D point to be projected into 2-D
XP:, YP:, ZP:	(output) coordinates of 2-D projection and (ZP) distance to viewer
XJ:, YJ:, ZJ:	(output) coordinates of 3-D reverse-projection point
XI:, YI:, ZI:	coordinates of 2-D point to be reverse-projected and (ZP) distance to viewer of 3-D point to be found

Purpose: PPJSET sets up the 3-D to 2-D and 2-D to 3-D projection matrices. PRSPPJ projects from 3-D to 2-D; PRSPPK projects from 2-D to 3-D. The method is as follows:

Imagine a camera properly oriented to take a picture of a collection of points and line segments. Let P_v be the point at the center of the lens of the camera and let P_q be a point that is directly in front of the lens so that its image is focused on the center of the plate. The line lying on the points P_v and P_q is the optic axis of the camera. Unless the optic axis is parallel to the z-axis, the camera will be rotated about the optic axis until the image of a vector pointing in the +z direction points straight up on the plate. If the camera is pointed straight up (or down), then the image of a vector pointing in +x direction will point to the right and the image of a vector pointing in the +y direction will point up (or down).

The plane perpendicular to the optic axis at the lens is the principal plane and the plane in which the plate lies is the focal plane. The distance between the focal plane and the principal plane is the focal length. The focal length determines the magnification of the camera. In fact, if a segment is perpendicular to the optic axis and if

H = the length of the segment

h = the length of the image of the segment

D = the distance between the segment and the principal plane

d = the focal length of the camera

then

$$h = d*H/D.$$

PTCOMP

Calling Sequence: SUBROUTINE PTCOMP (X1, X2, ISAM)

Called By: SHIELD
INTCHK
FINVER

Local Variables: X1(2): Point 1

X2(2): Point 2

ISAM: (output) ISAM = 0 implies X1 and X2 are different points; ISAM = 1 implies X1 and X2 are the same point.

Purpose: PTCOMP determines if the points X1 and X2 are the same point.

PTLINE

Calling Sequence: SUBROUTINE PTLINE (X1, X2, XP, IONFLG)

Called By: INTSEC

Local Variables:

X1(2):	Start of double-precision line segment
X2(2):	End of double-precision line segment
XP(2):	Double-precision point which may or may not lie on the line segment
IONFLG:	(output) IONFLG = 0 implies XP is not on the segment; IONFLG = 1 implies XP is on the segment.

Purpose: PTLINE determines if point XP (which must lie on the line formed by X1 and X2) is on the line segment bounded by X1 and X2.

ROUSP

Calling Sequence: SUBROUTINE ROUSP (IXYZ, IND, IROUS, BUF1, IOBPLT, IPER, PER, NX, NY, NZ)

Called By: TRILIN

Local Variables: IXYZ: IXYZ = 1, 2 or 3 specifies contours through a fixed x, y or z plane

IND: Fixed value of x, y or z; index in grid at which cut is to be taken

Purpose: ROUSP plots contours of the charge array, ROUS, at a specified cut. ROUS is only defined for the inner grid, and the 3-D plane at which the ROUS values are plotted is specified by a fixed x, y or z. IXYZ determines which dimension is fixed, and IND is the fixed value.

ROUSP also plots the satellite silhouette by reading in the building-block data from file IPLT = IABS(IOBPLT) and plotting the block perimeters in IPER = PER projected onto the appropriate plane.

SATPLT

Calling Sequence: SUBROUTINE SATPLT (NX, NY, NZ, IOBPLT)

Called By: NASCAP

Purpose: SATPLT is called when IOBPLT is greater than zero indicating satellite illustration plots are desired.

SATPLT first calls MATCAL to set up for and call MATPLT to generate the material composition satellite silhouettes.

Next, HIDCEL is called to generate 3-D plots for each of three default views, and for any additional views requested by user input.

C-4

SETFAC

Calling Sequence: SUBROUTINE SETFAC (I, IDIR, INDFAC, IWORD)

Called By: SETFWG, SETFOC, SETFTH, SETFFL

Local Variables:

I: I = 1, 2 or 3 implies an x, y, or z component of the block face normal.

IDIR: IDIR = 1, 0, or -1 implies set 01, 00, or 11 bit pattern for this component.

INDFAC: INDFAC specifies what face of the current block we are defining a normal for.

IWORD: Word currently being filled in with normal bit set patterns; following completion of this block's face normal definitions, IFAC(NBLK) will be set equal to IWORD.

Purpose: The IFAC(80) array stores block face normal information for up to 64 building blocks plus extra face storage for up to 16 octagons (which would already be part of the set of 64). For rectangular blocks, the faces are indexed 1 through 6 and face I will always have the same orientation and normal.

For blocks which are wedges, octagons, tetrahedra, or "FIL111" types, the input block is not symmetric in three dimensions, and a given face I of some block may have a normal different from the face I normal for a previous block of the same type if the two blocks are input with different orientations. (The array IPER=PER contains for each block a list of vertices, some of which are duplicated, which when traced out sequentially in 3-D draws the entire perimeter of the block. Face I for a given block type is defined as a particular subset of the vertices stored in PER for that block; e.g., vertices 4,

3, 8 and 5 might define face 2 of block type 2, which is a wedge. These face-definition data are stored in array IV in subroutine A2GEN.)

A block face normal may be defined by six bits; 0 and 1, 2 and 3, and 4 and 5 define three bit pairs for the x, y and z components of the normal, each pair of which can represent either a 1(01), 0(00) or -1(11). All block types except the octagon have at most six faces. Consequently, the first 64 words of IFAC contain, one word (36 bits) per block, normal information for up to six faces per block. The last 16 words contain, for a satellite with up to 16 octagons, the normal information for the last four octagon faces in bits 0-23.

For rectangles, because due to their 3-D symmetry of general shape, their orientation in the code is always the same, the specification of IFAC is a constant set of 36 bits. This constant is called IFACR and is defined in RECTAN in a data statement. For each rectangular block encountered, RECTAN is called and sets IFAC for this block equal to IFACR.

For the other four block types, however, a somewhat complex decoding of input orientation information must be made in order to correctly specify the face normal for each block in IFAC. For wedges, octagons, tetrahedra and FIL111 type blocks, the routines which fill in the set of PER perimeter vertices are WEDGES, NICOCT, TETRAH, and FIL111. Each of these routines calls, just after PER has been defined, one of SETFWG, SETFOC, SETFTH, or SETFFL. Each of these routines defines the cell face normal for its block type by filling in IFAC(NBLK) with a series of calls to SETFAC. SETFAC fills in a particular field of two bits with an 01, 00, or 11, according to whether IDIR equals 1, 0, or -1. Which pair of bits of the set of six for a given face is determined by I; I = 1, 2 or 3 implies the x, y, or z component is being defined. Which face is being treated (which field of 6 bits) is defined by INDFAC.

The building block cell face normals and vertex sets are necessary for the definition and sorting of A2 surface polygons in subroutine A2GEN.

SETFFL

Calling Sequence: SUBROUTINE SETFFL

Called By: FIL111

Purpose: SETFFL defines the block face normals in array IFAC for input blocks which are FIL111 type blocks. A series of calls to SETFAC fills in IWORD, and IFAC(NBLK) is set equal to IWORD (see SETFAC).

SETFOC

Calling Sequence: SUBROUTINE SETFOC (NBLK, NOCT, IFAC, I1, I2, I3)

Called By: NIOOCT

Local Variables: NBLK: Index of current block being defined.

NOCT: Number of octagons including current one, which have been encountered (defines which word of last 16 of IFAC will be used in storing normals for last 4 faces of this octagon).

I1: I2: I3: Some combination of 1, 2, and 3, specifying x, y and z components of block face normals.

Purpose: SETFOC defines the block face normals in array IFAC for input blocks which are octagons. A series of calls to SETFAC fills in IWORD and IFAC(NBLK) is set equal to IWORD for the first six faces, while IFAC(64 + NOCT) is set equal to a second IWORD for the last four faces (see SETFAC).

SETFTH

Calling Sequence: SUBROUTINE SETFTH (NBLK, IFAC, ID)

Called By: TETRAH

Local Variables: NBLK: Index of current block being defined.

ID(3): 1, 0 or -1 for normal specification.

Purpose: SETFTH defines the block face normals in array IFAC for input blocks which are tetrahedra. A series of calls to SETFAC fills in IWORD, and IFAC(NBLK) is set equal to IWORD (see SETFAC).

SETFWG

Calling Sequence: SUBROUTINE SETFWG (NBLK, IFAC, ID, I1, I2, I3)

Called By: WEDGES

Local Variables: NBLK: Index of current block being defined.

ID(3): 1, 0, or -1 for normal specification.

I1:, I2:, I3: Some combination of 1, 2, and 3, specifying x, y, and z components of block face normals.

Purpose: SETFWG defines the block face normals in array IFAC for input blocks which are wedges. A series of calls to SETFAC fills in IWORD, and IFAC(NBLK) is set equal to IWORD (see SETFAC).

SHIELD

Calling Sequence: SUBROUTINE SHIELD (N1, N2, A1, A2, ISHLD, N3, A3, IMASK, IFF1, IFF2, DV1, DV2, DIR, IA1, IA2, A1R, A2R, IP)

Called By: HIDCEL

Local Variables: N1: Number of vertices in A1

N2: Number of vertices in A2

N3(12): Number of vertices in up to 12 new polygons

Purpose: SHIELD finishes deciding if an A1 polygon is behind the current A2 polygon. If so, it masks the A1 polygon against the A2 polygon, placing new polygons created (representing the unshielded portion(s) of the original A1) into the A3 array. ISHLD indicates the number of new polygons created by this masking. ISHLD = 0 implies A1 was completely shielded by A2. ISHLD = -1 implies no shielding took place, either because there was no overlap or because A1 was in front of A2.

Internal Organization: SHIELD first generates A1D and A2D, double precision copies of the A1 and A2 vertices for use in INSIDD and INTCHK calculations demanding double precision accuracy.

A loop over the A1 vertices determines whether each A1 vertex is inside A2 or not by calling INSIDD (on the perimeter is inside). Within this loop we also perform a behindness-checking algorithm if IMASK = 0 and if the current vertex is inside A2. PRSPPK finds a 3-D point on the line between the 3-D surface cell vertex and its 2-D focal plane projection (see PRSPPJ). The 3-D line defined by the 3-D lens point (see PRSPPJ) and this new 3-D point is the line between the 3-D vertex and the 2-D projection. LINPLN recaptures and places in XINTA1 the original 3-D coordinates of the A1 vertex by finding the intersection of the line with the plane of the A1

polygon as determined by its normal in IFF1(IA1), bits 0-5, and point A1R. A1R is one 3-D vertex of A1; we cannot store all 3-D vertices for the A1's due to storage considerations. (Note: We do store all 3-D coordinates for the A2 polygons in A2R, since there are far fewer of these.) LINPLN is also called to find the 3-D point on the plane of A2 which this line intersects. This point is placed in XINTA2. Since the line from the 3-D vertex through the lens point to the 2-D projected point represents the direction of viewing for this point, the distances to the viewer of XINTA1 and XINTA2 indicate whether A1 is behind or in front of A2. PRSPPJ calculates these two distances, DA1 and DA2.

If the two distances are equal, then this A1 vertex is actually on A2 in 3-D. We keep track of the number of such vertices by incrementing NDA2 for each of these cases. If NDA2 reaches 3, indicating that at least three vertices of A1 are on A2, the two planes are the same and A1 must be on A2. We skip out of shield and skip this polygon combination. (If we masked A1 polygons against the A2's on which they lie, the whole satellite would disappear.)

If DA2 is greater than DA1, then A1 is closer to the viewer than A2 at this point, which implies that all of A1 is closer than A2 due to the A1's being single-cell polygons. ISHLD is set to -1 and we skip this combination.

If DA1 is greater than DA2, then A2 is closer to the viewer than A1, and we must mask A1 by A2. IMASK is set to 1 so no more behindness testing will be done.

The inside testing is done for each A1 vertex, and the behindness algorithm checked for each A1 vertex which is inside A2 until IMASK is set to 1. It may happen either that no A1 vertices are in A2 or that those that are yield only inconclusive behindness tests. In this case IMASK may still equal zero at the end of this loop. If NDA2 equals 2 at this

point, we have A1 adjacent to A2 and set ISHLD = -1 to specify skipping this combination. If all vertices of A1 are inside A2, then A1 is completely inside A2 (since A2 polygons must be convex in this code), and we return with ISHLD = 0.

A similar loop on A2 vertices follows. For each A2 vertex, INSIDD determines if the vertex is inside A1. If IMASK = 1, no behindness testing is done. Otherwise, for A2 vertices inside A1 we call LINPLN to find the point on the A1 plane which the line from the current 3-D A2 vertex to the lens point intersects (we need not use PRSPPK to find the 3-D vertex since we save all of these for A2's in A2R). We call PRSPPJ to calculate the distance to the viewer of this A1 plane intersection point. We already have this distance for the A2 vertex stored in DV2 (another example of information stored for A2 polygons but not for A1's).

We compare these two distances, DA1 and DV2. If DA1 = DV2 we increment NDA1. Unless NDA1 reaches three, indicating an error, this information is inconclusive. However, if DA1 is less than DV2, we may return with ISHLD = -1 again, since A1 is in front of A2; and, if DA1 is greater than DV2, we set IMASK = 1 to avoid any further behindness tests.

We determine whether each A2 vertex is inside A1, and if IMASK = 0 at this point, check for behindness for A2 vertices which are in A1, until IMASK is set to 1 or until we finish the set of A2 vertices.

It is possible for IMASK to equal 0 at this point but for masking still to be necessary; for example, if two long rectangles at right angles cross at their middles, neither will have any vertices within the other, hence no behindness testing will have been done in the previous two loops. This and other somewhat pathological cases must be tested for behindness when some intersection point of the two polygons is found by the masking algorithm. In this case, an

algorithm identical to that in the first loop is used to determine behindness.

The remainder of the routine masks the A1 polygon by the A2 polygon by following the A1 perimeter around from start to finish, making note of all intersections with the A2 perimeter, and opening and closing new polygons as is appropriate. A "new polygon" is a portion of the A1 polygon which lies completely outside A2 and is composed of one or more A1 vertices and two intersection points with the A2 perimeter (these may, of course, also be A1 vertices in certain cases). The A2 perimeter intersection points mark the start and finish of the "new polygon" at this point, but may or may not lie on the same A2 side. If they do lie on the same A2 side, then the polygon is already complete. If they do not, however, then to complete the new polygon we must find that set of A2 vertices which lie on that part of the A2 perimeter between the start and finish points of the new polygon. Whether the start and finish points lie on the same side or not, the task of finishing the vertex set of a new polygon is performed by subroutine FINVEK.

Following the inside tests and behindness checking, a loop over the segments of A1 begins. A segment of either polygon is referenced by the vertex starting it: segment 1 goes from vertex 1 to 2, segment 2 from vertex 2 to 3, and the last segment from vertex N to vertex 1. The first vertex information is appended to all appropriate lists to facilitate handling of the last segment.

If the last vertex of the current A1 segment is outside A2, it is added to the current new polygon vertex list. Next, we call INTCHK which checks the current A1 segment for intersections with all A2 segments. INTCHK returns INT = number of distinct intersections with the A2 perimeter. If INT = 0, we go onto the next A1 segment.

If INT $\neq$ 0, then INTCHK has also returned all intersection points in array XINT, and information (NA2SEG) telling how many A2 segments this A1 segment intersected at each intersection point (if it intersects at an A2 vertex, then it has intersected two A2 segments at that intersection point). It also returns IA2SEG indicating which A2 segment the A1 segment intersects. FINVER will use this information.

A loop over the number of intersection points follows. If the current intersection point is the same as the last one treated, we skip it. (There are certain tests here to avoid skipping such a point if it is needed both to start the first new polygon and end the last one.) If we keep this intersection point, we add it into the current new polygon by incrementing INEW (number of points in the new polygon) and by moving the intersection point into A3 (INE , NEW).

Before we actually move the point into A3, however, we must check if, for INEW = 2, we have a segment which is completely within A2. If so, we must discard the INEW = 1 point and start our new polygon with the current intersection point. We determine this by finding the midpoint of the segment from the INEW = 1 point to the INEW = 2 point. Since A2 must be convex, if this midpoint is inside A2, we discard this segment, while if it is outside, we keep the segment.

It is at this point that we check for behindness once again if IMASK is still equal to zero.

Since the current point is an intersection point, it must either open or close a new polygon. If INEW is equal to 1, we are opening a new polygon and go on to the next intersection point (if there are no more, we go on to the next A1 segment).

If INEW is greater than 1, we are closing a new polygon. If this is the second intersection point in this new polygon, we may call FINVER at this point to finish its vertex set.

(The first and last new polygons may need to be added together to form a complete new polygon with two intersection points, depending on which A1 vertex we started at.)

We close this new polygon by incrementing NEW, the number of new polygons and by resetting INEW to zero.

We then check to see if the current intersection point is an A2 vertex. If so, we must count it not only as the last point of the last new polygon, but also as the opening point of the just-opened new polygon. If this is so, we set INEW = 1, and move the appropriate information into place for the new polygon.

We then loop back to finish any more intersection points for the current A1 segment. When these are exhausted, we loop back to the next A1 segment. When all A1 segment vertices and intersection points have been exhausted, we reach statement label 70. Here we know that there has been at least one intersection, and our task is to determine if either or both of the first and last new polygons are incomplete. If the first one is incomplete, we join it to the last one. If the first one is complete, we either keep or discard the last one depending on whether it is complete or not. A polygon to be discarded might be, for example, a one-point polygon.

If the first and last polygons are added together, FINVER is called to complete the vertex set. We are now finished and jump to 300 to perform final checks and return to HIDCEL.

If we reach the end of the 200 loop, there have been no intersections at all. If this is so, and neither polygon had any vertices inside the other, then there is no overlap and we return with ISHLD = -1.

If all vertices of A1 are inside A2, A1 is completely shielded and we return with ISHLD = 0 (this has already been

checked earlier in the routine). If all vertices of A2 are inside A1 and there have been no intersections we error return with a RETURN 0. We do not allow an A2 polygon to be completely enclosed within an A1 polygon with no intersections.

10. NASCAP COMMON BLOCKS

Common Block	Map Segment	Contents/Purpose
AN	FLUXES	IVN(3,3),A(3,3,3)/Transformation matrix for velocities.
AREAS	CHARGE	AREAS(1024)/Sun exposed areas of surface cells.
BLOCKS	NASCAP	II(17,33), IBM(33)/Bit arrays.
CBUF	TRILIN	BUF1(17,17,33), BUF2(17,17,33), BUF3(17,17,33)/Storage area for TRILIN, CHARGE POTENT.
CD	MATPLT	XD, YD.
CENT	CHARGE	ICX(3), CENT(3)/Mesh center coordinates.
CIPRT	POTENT	IPRT.
CIT	NASCAP	NCYC, MAXITR, INTITR, POTEPS, MCYC, IALG.
CITER	TRILIN	ITER.
CONOPT	NASCAP	NCON, ICNOPT(2,8).
COPT	NASCAP	ICREST, IPREST, IOBCAL, ICON, ICNVP, IOUTER, ITYPE.
FLUX	TRILIN	Flux definition parameters.
HIDOPT	NASCAP	NDIR, DIROPT(3,5).
IGFBLK	NASCAP	Graphic output use.
INDATC	TRILIN	ICYC1, ICYC2, IG, ISSAVE, NXYZ, PCOND(7), QCOND(7), QSUM0, IPSAVE, ICYCS.
IOCLS	TRILIN	IOMAX, IOCLS(128)/Cells for output by IOFLX.
IUNIT	NASCAP	Logical unit numbers for external files.
I0031	CNVPLT	Printer-plotter scratch space.

Common Block	Map Segment	Contents/Purpose
LENS	HIDCEL	VX, VY, VZ, FL, DFAC.
LSTSRF	OBJCOM	LIST(1024), WPCOND(1024), W(27,1024)/ Large storage area for OBJDEF.
MAGDIP	TRILIN	BFLDO(3), NDIP, PRDIP(6,10)/ Magnetic field information.
MATLS	NASCAP	NMAT, MCODE(15), MATPR(20,15)/ Material names and properties.
MATLS2	MATPLT	(identical to MATLS).
MATOPT	NASCAP	NDIV(6), NDVAL(2,5,6).
MCOND	TRILIN	CIJ(7,7), CIJSUM(7), MBIAS, VBIAS(7), MFIX(7), VFIX(7).
MESH	NASCAP	XMESH, DELTA, ICYC, TIME, DELFAC.
MISC	NASCAP	SWPCND(7)/Potential coefficients.
MOROPT	TRILIN	LONGTM, SHEATH, POTSCL/Keyword options.
NPT	NASCAP	NSPTS, NPTS/Number of surface and special points.
NXYZG	CHARGE	NX,NY,NZ,NG.
OUTPOT	TNOPT	XS, YS, ZS.
PEROBJ	OBJDEF	NMCP, PMCND(7,100)/Multi-conductor point potential weights.
PHCUR	CHARGE	IR, IX1, IX2, IX3, JCURCL/Scratch variables in photosheath calculation.
PLOT	CNVPLT	Scratch area for printer-plotter routines.
PLTOPT	NASCAP	ITPART, ITCUR, IROUSP/Plot flags.
SCRACH	NASCAP	Various.
SRFPRM	CHARGE	KTP, ICND, MATNO, MKL(3), NCORN, POINTS(3,4), PCELL, FIELD/Surface cell parameters.

Common Block	Map Segment	Contents/Purpose
STOR	CHARGE	NBLK, NPBLK(64), PROJ(3,1024), FLOW(1024), FLUXES(1024), SPACER(1024)/Storage area for CHARGE segment.
SUNVEC	NASCAP	SUN(3), SFAC/Sun-direction and intensity.
SURF	OBJCOM	NSURF, JSURF(1024)/Surface cell list.
SURF2	MATPLT	(Identical to SURF).
SURF3	CHARGE	(Identical to SURF).
TANK	TRILIN	Flux information for test tank and reverse trajectory modes.
TNKSZ	TRILIN	IL, IR, ILGRD/Outer grid truncation.

11. VARIABLE GLOSSARY

The following is a glossary of major variables appearing in the major subroutines of NASCAP. Subroutines or subroutine groups in which a variable is defined or used are indicated. Routines in which a variable is merely passed along to another level are not normally included. If a variable appears in a common block, this is indicated first.

Variable definitions are as concise and complete as possible. However, some reference to documentation of relevant subroutines or subroutine groups in other sections of this report is made where appropriate.

If a variable is an input to the code, this is indicated. Variables in the runstream input file are referred to as "user-specified". If a variable is defined in another input file such as the keyword input file or the object definition file, this is indicated.

ALPHA

Appears In: CHARGE, POTENT

Meaning: (CHARGE) Used for potential scaling in connection with LONGTIMESTEP option.

(POTENT) Conjugate gradient algorithm scalar equal to $r^n \cdot r^n / u^n \cdot (Au)^n$.

AREA

Appears In: CHARGE, HIDCEL

Meaning: (CHARGE) Area of a surface cell in m^2.

AREAS; AREAS(1024)

Appears In: CHARGE

Meaning: Common block containing array of same name containing fraction of each surface cell exposed to sunlight.

AREA1(1024)

Appears In: HIDCEL

Meaning: First used to hold final shielded 2-D areas of surface cells; then holds those areas divided by original unshielded 2-D areas to yield final fractional areas with the dot product (angle) effect removed.

AREA2(1024)

Appears In: HIDCEL

Meaning: Original unshielded 2-D areas of surface cells.

AUNCON(7)

Appears In: POTENT and related routines.

Meaning: Conjugate gradient coefficient product $(Au)^n$ for conductors.

A1(2,12,600)

Appears In: HIDCEL and related routines.
Meaning: A1(1,I,J) and A1(2,I,J) are x and y coordinates of Ith vertex of Jth A1 polygon.

A1B(600)

Appears In: HIDCEL and related routines.
Meaning: A1B(I) is distance to viewer of vertex furthest from viewer for the surface cell which projects into the Jth A1 polygon.

A1BS

Appears In: HIDCEL, ADDA1
Meaning: Temporary save of A1B(IA1).

A1BT

Appears In: HIDCEL
Meaning: Temporary save of A1B(IA1).

A1F(600)

Appears In: HIDCEL and related routines.
Meaning: A1F(I) is distance to viewer of vertex closest to viewer for the surface cell which projects into the Ith A1 polygon.

A1FS

Appears In: HIDCEL, ADDA1
Meaning: Temporary save of A1F(IA1).

A1FT

Appears In: HIDCEL
Meaning: Temporary save of A1F(IA1).

A1R(3,600)

Appears In: HIDCEL and related routines

Meaning: A1R(1,I), A1R(2,I), and A1R(3,I) are x, y and z coordinates of first vertex of 3-D surface cell which projects into Ith A1 polygon. Used with surface cell normal to define plane of cell for LINPLN (see SHIELD).

A1RS(3)

Appears In: HIDCEL, ADDA1

Meaning: Temporary save of (A1R(K,IA1),K=1,3).

A2(2,9,150)

Appears In: HIDCEL and related routines.

Meaning: A2(1,I,J) and A2(2,I,J) are x and y coordinates of Ith vertex of Jth A2 polygon.

A2B(150)

Appears In: HIDCEL and related routines.

Meaning: A2B(I) is distance to viewer of vertex furthest from viewer for the building-block face which projects into the Ith A2 polygon.

A2BT

Appears In: HIDCEL

Meaning: Temporary save of A2B(IA2).

A2F(150)

Appears In: HIDCEL and related routines.

Meaning: A2F(I) is distance to viewer of vertex closest to viewer for the building-block face which projects into the Ith A2 polygon.

A2FT

Appears In: HIDCEL

Meaning: Temporary save of A2F(IA2).

A2R(3,9,150)

Appears In: HIDCEL and related routines.

Meaning: A2R(1,I,J), A2R(2,I,J), A2R(3,I,J) are x, y and z coordinates of Ith vertex of building-block face which projects into Jth A2 polygon.

A3(2,24,12)

Appears In: HIDCEL and related routines.

Meaning: A3(1,I,J), A3(2,I,J) are x and y coordinates of Ith vertex of Jth new polygon being created by SHIELD.

BETA

Appears In: CHARGE, POTENT

Meaning: (CHARGE) Factor used in LONGTIMESTEP correction.

(POTENT) Conjugate gradient algorithm scalar equal to $-r^n \cdot (Au)^n / u^n \cdot (Au)^n$.

BUF1(17,17,33)

Appears In: COMMON/CBUF/; POTENT and related routines; other routines.

Meaning: First of three identical buffer storage arrays used mainly for conjugate gradient array storage of one grid's worth of data at a time. Used in other parts of code for other purposes as well, sometimes under different names.

BUF2(17,17,33)

Appears In: COMMON/CBUF/; POTENT and related routines; other routines.

Meaning: Second of three identical buffer storage arrays used mainly for conjugate gradient array storage of one grid's worth of data at a time. Used in other parts of code for other purposes as well, sometimes under different names.

BUF3(17,17,33)

Appears In: COMMON/CBUF/; POTENT and related routines; other routines.

Meaning: Third of three identical buffer storage arrays used mainly for conjugate gradient array storage of one grid's worth of data at a time. Used in other parts of the code for other purposes, sometimes under different names.

C

Appears In: POTENT and related routines.

Meaning: Conjugate gradient algorithm scalar (for algorithm 1): $C^{i+1} = 1. + BETA*C^{i}$.

CENT; CENT(3)

Appears In: CHARGE

Meaning: Common block containing array with values (NX/2+1), (NY/2+1), (NZ/2+1).

CIJ(7,7)

Appears In: COMMON/MCOND/; POTENT and related routines; INKEYW.

Meaning: CIJ(I,J) is capacitance between Ith and Jth conductors associated with glue joint or insulating spacer.

CIJSUM(7)

Appears In: COMMON/MCOND/; POTENT and related routines; INKEYW.

Meaning: $CIJSUM(I) = \sum_{J} CIJ(I,J)$.

CNET

Appears In: CHARGE

Meaning: Net charging current.

CNET2

Appears In: CHARGE

Meaning: Net charging current at advance timestep computed by LONGTIMESTEP option.

CS

Appears In: POTENT

Meaning: Temporary save of C^i after C has been set to C^{i+1}.

DELFAC

Appears In: CHARGE

Meaning: Factor by which DELTA is multiplied after each cycle; runstream input.

DELTA

Appears In: CHARGE

Meaning: Length of timestep in seconds; runstream input.

DFAC

Appears In: HIDCEL

Meaning: Constant specifying distance to viewer from satellite center.

DIR(3,3)

Appears In: SATPLT, HIDCEL

Meaning: (SATPLT) DIR(1,I), DIR(2,I) and DIR(3,I) are x, y and z components of the direction-of-view vector pointing from the center of the satellite toward the viewer, for the Ith default satellite illustration view.

(HIDCEL) DIR(1), DIR(2), and DIR(3) are the x, y and z components of the normalized direction-of-view vector for the current HIDCEL cell.

DIROPT(3,5)

Appears In: SATPLT

Meaning: DIR(1,I), DIR(2,I), and DIR(3,I) are the x, y and z components of the Ith user-specified optional satellite illustration view.

DNORM

Appears In: HIDCEL

Meaning: Length of unnormalized direction-of-view vector PDIR(3) input to HIDCEL.

DUM

Appears In: NASCAP, CHARGE, HIDCEL, CONPLT, ROUSP, PARPLT

Meaning: Dummy read variable for quick skip of a binary record on an external file.

DV1

Appears In: HIDCEL, AIGEN

Meaning: Not currently used.

DV2(9,150)

Appears In: HIDCEL and related routines.

Meaning: DV2(I,J) is the distance to viewer of the Ith vertex of the building-block face which projects into the Jth A2 polygon.

FLOW(1024)

Appears In: CHARGE

Meaning: Low energy electron flux emitted from each surface cell.

FLUXES(1024)

Appears In: CHARGE

Meaning: Net flux to each surface cell.

IALG

Appears In: INOPT, TRILIN, POTENT

Meaning: User-specified input determining which conjugate gradient potential solution algorithm will be used: IALG = 0 implies algorithm 0; IALG = 1 implies algorithm 1.

IAREA

Appears In: COMMON/IUNIT/; NASCAP, INOPT, HIDCEL

Meaning: User-specified I/O unit number of external file on which shadowed surface cell areas (AREA1) are written. If IAREA > 0, a new sun direction vector (SUN) is used to make a new shadowing calculation. If IAREA < 0, the old shadowed areas on unit IABS(IAREA) are used. When HIDCEL is called from SATPLT with argument IAREA = 0, no area calculations are made, and the non-hidden line building-block plot is made in addition to the hidden line cell-by-cell plot.

IAUN

Appears In: COMMON/IUNIT/; INOPT; POTENT and related routines.

Meaning: User-specified I/O unit number of external file containing $(Au)^n$, conjugate gradient coefficient product values for grid points.

IA1

Appears In: HIDCEL and related routines.

Meaning: Index of current A1 polygon.

IA1T

Appears In: HIDCEL

Meaning: Index in original surface cell list of 1024 cells of the surface cell which generated parent (original, unshielded) A1 polygon of current A1 polygon, where final polygon information is printed.

IA1TT

Appears In: HIDCEL

Meaning: Index in original surface cell list of 1024 cells of the surface cell which generated parent (original, unshielded) A1 polygon of current A1 polygon in shielding loops.

IA2

Appears In: HIDCEL and related routines.

Meaning: Index of current A2 polygon.

IBM(33)

Appears In: NASCAP, CHARGE, OBJDEF,/BLOCKS/

Meaning: A bit mask array: IBM(I) = 2**(I-1).

IC

Appears In: HIDCEL, OBJDEF, POTENT

Meaning: (HIDCEL) Loop index over surface cell area list; 1-1024.

(OBJDEF) Loop index over conductors; 1-7.

(POTENT) Loop index over conductors; 1-7.

ICNVP

Appears In: COMMON/COPT/; INOPT, TRILIN

Meaning: User-specified input flag indicating whether or not and how often potential convergence printer plots are desired: ICNVP $\leq$ 0 implies no plots; ICNVP > 0 implies plot convergence data every ICNVP time cycles, starting with cycle 1.

ICON

Appears In: COMMON/COPT/; NASCAP, INOPT, TRILIN

Meaning: User-specified input flag indicating whether or not and how often potential contour plots are desired. ICON $\leq$ 0 implies no plots; ICON > 0 implies plot potential contours every ICON time cycles, starting with cycle 1.

ICREST

Appears In: COMMON/COPT/; INOPT, INDATA, TRILIN

Meaning: User-specified new time cycle restart flag: ICREST = 0 implies fresh start of new problem if IPREST = 0, or potential calculation restart at same time cycle as last run if IPREST $\neq$ 0. ICREST = 1 implies restart at beginning of the time cycle following last time cycle of previous run.

ICYC

Appears In: COMMON/MESH/; TRILIN, CHARGE, POTENT

Meaning: Index of current time cycle.

ICYCS

Appears In: COMMON/INDATC/; INDATA, TRILIN

Meaning: Temporary save of last cycle completed. Saved upon run completion for restarts.

ICYC1

Appears In: COMMON/INDATC/; INDATA, TRILIN

Meaning: Index of time cycle at which this run will begin. Equals 1 for a fresh start. Equals (ICYC2 of last run + 1) for a cycle restart. Equals ICYC2 of last run for a potential restart.

ICYC2

Appears In: COMMON/INDATC/; INDATA, TRILIN

Meaning: Index of last time cycle which this run will complete. Equals ICYC1 + NCYC - 1.

IFAC(80)

Appears In: COMMON/LSTSRF/(in OBJDEF routines); RECTAN, WEDGES, NIOOCT, TETRAH, FIL111, SETFWG, SETFOC, SETFTH, SETFFL, HIDCEL, A2GEN

Meaning: IFAC(I) = 1,64 contains bit encoded data specifying the block face normals for the first six faces of the Ith satellite building block. The 36 bits form six groups of six bits each; for a group of six, the first two bits specify the x component, the second two bits the y component, and the third two bits the z component of the normal as follows: 00 = 0; 01 = 1; 11 = -1; 10 not permitted. The last sixteen words of IFAC contain bit encoded data for normals for the last four faces of up to sixteen octagonal blocks (the only block type with more than six faces). See subroutine SETFAC.

IFFS

Appears In: HIDCEL, ADDA1

Meaning: Temporary save of IFF1(IA1).

IFF1(600)

Appears In: HIDCEL and related routines.

Meaning: IFF1(I) contains bit encoded data indicating the surface cell normal and index for the surface cell which projected into the Ith I1 polygon. Bits 0,1: x component of normal; Bits 2,3: y component of normal; Bits 4,5: z component of normal, where 00 = 0, 01 = 1, 11 = -1, 10 not permitted. Bits 6-15: index (1-1024) in surface cell list of parent surface cell.

IFF2(150)

Appears In: HIDCEL and related routines.

Meaning: The first six bits of IFF2(I) contain bit encoded data indicating the block face normal of the building-block face which projected into the Ith A2 polygon, exactly as IFF1 stored A1 polygon normals.

II(17,33)

Appears In: NASCAP, OBJDEF, OBJSPC,/BLOCKS/ AND (II(IY,IZ), IBM(IX)) $\neq$ 0 if point (IX,IY,IZ) is a special, surface or interior point.

IM

Appears In: POTENT

Meaning Loop index over biased conductors in ROUSCN definition.

IMASK

Appears In: HIDCEL, SHIELD

Meaning: IMASK = 0 implies we do not yet know if A1 is behind A2. IMASK = 1 implies we have ascertained that A1 is behind A2 and we must therefore mask A1 by A2. See subroutines HIDCEL and SHIELD.

INTITR

Appears In: COMMON/CIT/; INOPT, POTENT

Meaning: User-specified input flag specifying that the conjugate gradient algorithm is to be reinitialized every INTITR iterations (not normally used).

IOBCAL

Appears In: COMMON/COPT/; INOPT, NASCAP

Meaning: User-specified input flag for OBJDEF call: IOBCAL = 1 implies call OBJDEF and proceed normally. IOBCAL = 0 implies skip OBJDEF call and proceed normally (in this case OBJDEF must have been called for the current satellite in a previous run). IOBCAL = -1 implies call OBJDEF (and SATPLT and HIDCEL if called for), and stop.

IOBJ

Appears In: COMMON/IUNIT/; INOPT, OBJDEF, OBJSPC

Meaning: I/O unit number of external file on which OBJDEF writes the PMCND, LIST, WPCOND, and W arrays for use by OBJSPC.

IOBPLT

Appears In: COMMON/IUNIT/; INOPT, OBJDEF, NASCAP, ETNGUN, SOURCE, CONPLT, PARPLT, ROUSP, HIDCEL, MATPLT

Meaning: User-specified I/O unit number of external file on which OBJDEF writes satellite definition data, and from which all plot routines, etc., reading this data read it. Also a flag indicating whether or not satellite illustration plots are desired. IOBPLT > 0 implies plot material composition satellite silhouettes, non-hidden line satellite building-block plots, and hidden-line cell-by-cell plots. IOBPLT < 0 implies do not plot, and use unit number IPLOT = IABS(IOBPLT).

IP

Appears In: COMMON/IUNIT/; INOPT, TRILIN, POTENT and related routines, CHARGE and related routines, CONPLT

Meaning: User-specified I/O unit number of external file in which grid potentials are stored.

IPART

Appears In: COMMON/IUNIT/; INOPT, NASCAP, TRILIN, PUSH, PARPLT

Meaning: User-specified I/O unit number of external file on which PUSH writes particle trajectory data for plotting by PARPLT. Also a flag indicating whether or not particle trajectory plots are desired. IPART > 0 implies write particle trajectory data for particles landing in cell IOCL(1) onto file IPART, and plot these trajectories for the first cycle of the run in subroutine PARPLT.

IPER(3,32,64)

Appears In: COMMON/LSTSRF/(in OBJDEF and related routines); HIDCEL, CONPLT, ROUSP, PARPLT, ETNGUN, SOURCE

Meaning: Same storage as PER in all routines except OBJDEF. Integer version of data in PER. IPER(1,I,J), IPER(2,I,J), and IPER(3,I,J) are the x, y and z coordinates of the Ith vertex in the complete-perimeter vertex list for satellite block J. For each block, OBJDEF generates a complete-perimeter vertex list, containing some duplicated vertices, which when traced out in sequence defines the entire block perimeter.

IPFLAG

Appears In: NASCAP

Meaning: IPFLAG is set to one if any plots are called for by user input; otherwise it is zero. IPFLAG is used to determine whether a plot file must be opened and closed.

IPLOT

Appears In: NASCAP, INOPT, OBJDEF, CHARGE, ETNGUN, SOURCE

Meaning: IPLOT = IABS(IOBPLT).

IPREST

Appears In: COMMON/COPT/; INOPT, TRILIN, INDATA

Meaning: User-specified potential restart flag.
IPREST = 0 implies begin with new potential calculation at next cycle (cycle 1 if ICREST = 0, or cycle following last cycle of previous run if ICREST = 1).
IPREST = 1 implies restart in the middle of the previous run's last cycle potential calculation by re-initializing the conjugate gradient algorithm with the last run's final potentials as the initial guess. Take the last run's potentials from file IP.
IPREST < 0 implies restart as for IPREST = 1, but take the last run's potentials from file IPRDP = IABS(IPREST).

IR

Appears In: COMMON/IUNIT/; INOPT; POTENT and related routines.

Meaning: User-specified I/O unit number of external file on which the conjugate gradient array r (for grid points) is stored.

IREMOV(600)

Appears In: HIDCEL, A1COMP

Meaning: A1 polygon removal flag. If A1 polygon IA1 is partially or wholly shielded by the current A2 polygon, then IREMOV(IA1) is set to 1. Otherwise IREMOV(IA1) = 0.
IREMOV is used by A1COMP to remove unnecessary A1 polygons from the A1 information arrays. See subroutines HIDCEL and A1COMP.

IROUS

Appears In: COMMON/IUNIT/; INOPT, POTENT and related routines; CHARGE and related routines.

Meaning: User-specified I/O unit number of external file on which the ROUS charge array lies.

IROUSP

Appears In: COMMON/PLTOPT/; INOPT, NASCAP, TRILIN

Meaning: User-specified plot flag for ROUS contour plots. IROUSP = 0 implies no plots. IROUSP $\neq$ 0 implies plot final ROUS contours.

ISAT

Appears In: COMMON/IUNIT/; INOPT, OBJDEF and related routines.

Meaning: User-specified I/O unit number of the external file containing satellite definition input to OBJDEF.

ISHLD

Appears In: HIDCEL, SHIELD

Meaning: ISHLD $\geq$ 0 implies that masking of the current A1 polygon by the current A2 polygon has produced ISHLD new polygons (if ISHLD = 0 the A1 polygon was completely masked by the A2 polygon). ISHLD = -1 implies no masking occurred either because A1 was in front of A2 or because the polygons did not overlap.

ISPARE

Appears In: COMMON/IUNIT/; INOPT, POTENT and related routines.

Meaning: I/O unit number of the external file which is currently "spare", i.e., whose data is currently obsolete. See description of conjugate gradient potential solution.

ITCUR

Appears In: COMMON/PLTOPT/; INOPT, NASCAP, SOURCE

Meaning: User-specified plot flag for tank test current contours. ITCUR = 0 implies no plots. ITCUR $\neq$ 0 implies plot current contours.

ITER

Appears In: COMMON/CITER/; POTENT and related routines.

Meaning: Index of current potential iteration in conjugate gradient solution.

ITPART

Appears In: COMMON/PLTOPT/; INOPT, NASCAP, ETNGUN

Meaning: User-specified plot flag for tank test particle trajectory plots. ITPART = 0 implies no plots. ITPART $\neq$ 0 implies plot particle trajectories.

ITYPE

Appears In: COMMON/COPT/; INOPT, CHARGE, FLXDEF

Meaning: User-specified problem type flag.
ITYPE = 1 implies test tank case.
ITYPE = 2 implies Maxwellian isotropic plasma approximation.
ITYPE = 3 implies particle-pushing space case with experimental (ATS-5) ambient plasma.

IU

Appears In: COMMON/IUNIT/; INOPT, POTENT and related routines.

Meaning: User-specified I/O unit number of external file on which the conjugate gradient array u (for grid points) is stored.

IV

Appears In: HIDCEL

Meaning: Loop index over vertices of a final A1 polygon when finding 2-D minima and maxima for plot user area definition.

IWARN

Appears In: POTENT, TRILIN

Meaning: (for S-Cubed only) At the start of the potential iteration loop, S3WARN is called to determine if the number used up all but a pre-specified amount of its allotted cpu time. If it has, IWARN is set to one which tells the run to attend to necessary plots and restart dumps, and then terminate. If not, IWARN remains zero and the run proceeds normally.

IY

Appears In: COMMON/IUNIT/; INOPT, POTENT and related routines.

Meaning: User-specified I/O unit number of external file on which the conjugate gradient array y (for grid points) is stored.

I3

Appears In: HIDCEL

Meaning: Index of new polygons created by last SHIELD call running from 1 to ISHLD as the new polygons are added to A1 by ADDA1.

JC

Appears In: POTENT

Meaning: Inner loop index (1 to MBIAS) of double loop over biased conductors which defines SWPCIJ and SSCIJ.

JM

Appears In: POTENT

Meaning: Inner loop index (1 to MBIAS) of double loop over biased conductors which defines ROUSCN.

JSURF(1024)

Appears In: CHARGE, HIDCEL, OBJDEF

Meaning: An array containing the internal codes for surface cells (Figure 6.14).

MAXCYC

Appears In: POTENT

Meaning: Parameter equal to 100 which defines size of RITER, UITER and PCITER storing potential convergence printer plot data for up to 100 potential iterations.

MAXIDF

Appears In: INOPT

Meaning: Default value of MAXITR. If MAXITR as read in is negative, MAXITR will be set equal to MAXIDF = 50.

MAXITR

Appears In: COMMON/CIT/; INOPT, POTENT

Meaning: User-specified limit on the number of potential iterations. Currently there are no convergence tests and POTENT will iterate MAXITR times no matter what (unless S3WARN indicates cpu time is running low).

MBIAS

Appears In: COMMON/MCOND/; INKEYW, POTENT and related routines.

Meaning: Index of last biased conductor (= number of biased conductors including conductor one). Defined via the Keyword Input file.

MBIAS1

Appears In: POTENT

Meaning: MBIAS + 1. Index of first non-biased conductor.

MCYC

Appears In: COMMON/CIT/

Meaning: User-specified flag indicating whether or not and how often the potential solution will be performed. MCYC = 0 implies no potential solution; old or scaled potentials will be used. MCYC > 0 implies potentials will be solved when ICYC = 1 mod MCYC.

MFIX(7)

Appears In: COMMON/MCOND/; INKEYW, POTENT and related routines.

Meaning: Fixed potential conductor flag. MFIX(I) = 0 implies conductor I is not fixed. MFIX(I) = 1 implies conductor I is fixed.

MINITR

Appears In: POTENT

Meaning: Iteration at which the potential iteration loop will begin. Normally equals one, but if INTITR is non-zero, MINITR may be reset to (N*INTITR) + 1.

NA1

Appears In: HIDCEL and related routines.
Meaning: Number of A1 polygons currently in the A1 information arrays.

NA1M

Appears In: HIDCEL and related routines.
Meaning: Parameter equal to 600 used in defining A1 information array sizes. No more than NA1M A1 polygons may exist before list compression by A1COMP.

NA1NEW

Appears In: HIDCEL, A1COMP
Meaning: Output from ADDA1 indicating the total number of old A1 polygons plus the number of new ones which have been appended to the A1 lists by masking with the current A2 polygon. See HIDCEL.

NA2

Appears In: HIDCEL and related routines.
Meaning: Total number of A2 polygons.

NBLK

Appears In: COMMON/LSTSRF/(in OBTDEF); OBJDEF, HIDCEL, A2GEN, CONPLT, ROUSP, PARPLT, ETNGUN, SOURCE
Meaning: Number of satellite definition blocks ("building-blocks") as defined in the OBJDEF input file ISAT.

NC

Appears In: OBJDEF, POTENT and related routines;

Meaning: Number of conductors in current run.

NCMAX

Appears In: NASCAP, INOPT, OBJDEF and related routines; TRILIN, INDATA, CHARGE and related routines; POTENT and related routines.

Meaning: Parameter equal to 7. Maximum allowable number of conductors.

NCON

Appears In: COMMON/CONOPT/; INOPT, TRILIN

Meaning: User-specified number of optional potential contour plot cuts desired (normally zero).

NDIR

Appears In: COMMON/HIDOPT/; INOPT, SATPLT

Meaning: User-specified number of optional satellite illustration views for the three-dimensional plots.

NG

Appears In: Entire code. COMMON/NXYZG/(in CHARGE and related routines).

Meaning: User-specified number of nested NX x NY x NZ grids in the problem.

NITERP

Appears In: TRILIN, POTENT

Meaning: Number of potential iterations for which potential convergence printer plot data has been stored.

NMCMAX

Appears In: OBJDEF and related routines; POTENT and related routines.

Meaning: Parameter equal to 100. Maximum allowable number of multiple-conductor points. See OBJDEF.

NPBLK(64)

Appears In: COMMON/LSTSRF/(in OBJDEF); OBJDEF and related routines; HIDCEL, A2GEN, CONPLT, ROUSP, PARPLT, ETNGUN, SOURCE.

Meaning: NPBLK(I) is the number of points in the IPER complete perimeter list for satellite input block I. See IPER.

NPTS

Appears In: NASCAP, OBJDEF

Meaning: The number of special points.

NSPTS

Appears In: NASCAP, OBJDEF

Meaning: The number of surface points.

NSURF

Appears In: CHARGE, HIDCEL, OBJDEF

Meaning: The number of surface cells.

NTOTMX

Appears In: OBJDEF and related routines; OBJSPC.

Meaning: Parameter equal to 1024. Maximum allowable number of surface cells, surface points, or special points.

NV

Appears In: HIDCEL and related routines.

Meaning: Temporary storage of NV1(I) for use as a do loop limit.

NV1(600)

Appears In: HIDCEL and related routines.

Meaning: NV1(I) is the number of vertices in the Ith A1 polygon (including the repeat of the first vertex at the end of the list). See HIDCEL.

NV2(150)

Appears In: HIDCEL and related routines.

Meaning: NV2(I) is the number of vertices in the Ith A2 polygon (including the repeat of the first vertex at the end of the list). See HIDCEL.

NVER

Appears In: HIDCEL and related routines.

Meaning: Parameter equal to 12. Maximum allowable number of vertices in any A1 polygon (including the repeat of the first vertex at the end of the list). Although all A1 polygons start out with a maximum of five vertices, as they are masked, they can become concave and/or many-sided. If the code attempts to generate a polygon with twelve distinct vertices (which will need thirteen spaces in the vertex array), it will error terminate. A2 polygons are static and have a maximum of nine vertices (8 + 1).

NVM1

Appears In: HIDCEL

Meaning: Number of vertices minus one for some polygon (hence the number of distinct vertices).

NVP1

Appears In: HIDCEL

Meaning: Number of vertices plus one for some polygon.

NX

Appears In: Entire code. COMMON/NXYZG/(in CHARGE and related routines).

Meaning: User-specified number of x direction grid points in each of the nested grids; normally 17.

NXM

Appears In: OBJDEF and related routines; TRILIN.

Meaning: Parameter equal to 17. Maximum allowable number of x direction grid points.

NY

Appears In: Entire code. COMMON/NXYZG/(in CHARGE and related routines).

Meaning: User-specified number of y direction grid points in each of the nested grids; normally 17.

NYM

Appears In: OBJDEF and related routines; TRILIN.

Meaning: Parameter equal to 17. Maximum allowable number of y direction grid points.

NZ

Appears In: Entire code. COMMON/NXYZG/(in CHARGE and related routines).

Meaning: User-specified number of z direction grid points in each of the nested grids; an integer of form $4n+1$, $4 \leq n \leq 8$.

NZM

Appears In: OBJDEF and related routines; TRILIN.

Meaning: Parameter equal to 33. Maximum allowable number of z direction grid points.

N3(12)

Appears In: HIDCEL, SHIELD and related routines.
Meaning: N3(I) is the number of vertices in the Ith new polygon being created by SHIELD. See subroutines HIDCEL and SHIELD.

N3T

Appears In: HIDCEL
Meaning: Temporary save of N3(I) for use as a do loop limit.

PCITER(100)

Appears In: POTENT, TRILIN
Meaning: Potential convergence printer plot storage for up to 100 iterations' worth of the potential on conductor one.

PCOND(7)

Appears In: POTENT and related routines; TRILIN, INDATA, CHARGE and related routines.
Meaning: PCOND(I) is the potential on conductor I.

PDIR(3)

Appears In: HIDCEL
Meaning: Unnormalized direction-of-view vector for this call to HIDCEL. See DIR(3).

PEPSDF

Appears In: INOPT
Meaning: Designed as a default epsilon for potential convergence tests. If POTEPS is read in as 0, it is set equal to PEPSDF. At present, no potential convergence tests are included in the code hence neither PEPSDF or POTEPS is used.

PER(3,32,64) [or PER(32,64) in OBJDEF]

Appears In: COMMON/JSURF/(in OBJDEF and related routines); HIDCEL, CONPLT, ROUSP, PARPLT, ETNGUN, SOURCE.

Meaning: In all routines except OBJDEF and its descendants, PER is a real copy of the integer information in IPER (in fact, it is the same storage area). In OBJDEF, PER holds the same information, but the data is bit-encoded three integers to a word: Bits 5 to 10: x coordinate; Bits 11 to 16: y coordinate; Bits 17 to 22: z coordinate. See IBM(33).

PHOJ(3,1024)

Appears In: CHARGE

Meaning: An array containing the photosheath currents in volume cells immediately surrounding the object.

PI

Appears In: POTENT

Meaning: 3.1415926.

POINTS(3,4)

Appears In: CHARGE

Meaning: An integer array containing the vertices of current surface cell.

POTSCL

Appears In: TRILIN

Meaning: A variable containing the potential scaling option literal.

P3(36,36)

Appears In: POTENT and related routines.
Meaning: Scratch storage for the I-prefix and O-prefix routines called by subroutines IRCALL and ORCALL.

QCOND(7)

Appears In: CHARGE and related routines; TRILIN, INDATA, POTENT and related routines.
Meaning: QCOND(I) is the charge on conductor I.

QNX2

Appears In: HIDCEL, PRSPPJ
Meaning: Real 3-D x coordinate of center of inner grid. Used by subroutine PRSPPJ (entry point PPJSET).

QNY2

Appears In: HIDCEL, PRSPPJ
Meaning: Real 3-D y coordinate of center of inner grid. Used by subroutine PRSPPJ (entry point PPJSET).

QNZ2

Appears In: HIDCEL, PRSPPJ
Meaning: Real 3-D z coordinate of center of inner grid. Used by subroutine PRSPPJ (entry point PPJSET).

QSUM

Appears In: TRILIN
Meaning: The total charge in the inner grid.

QSUMD

Appears In: TRILIN
Meaning: QSUM - (sum of charges on fixed potential conductors).

RCOND(7)

Appears In: POTENT and related routines.

Meaning: Conjugate gradient algorithm r array values for each of up to seven conductors. See subroutine POTENT.

RDOTAU (double precision)

Appears In: POTENT, RUPDAT

Meaning: Conjugate gradient array dot product $r^{n+1} \cdot (Au)^n$ used to calculate BETA. See subroutine POTENT.

RDOTR (double precision)

Appears In: POTENT, URSETO, RUPDAT

Meaning: Conjugate gradient array dot product $r^n \cdot r^n$.

RDOTRS (double precision)

Appears In: POTENT, RUPDAT

Meaning: Temporary save of previous iterations RDOTR after RDOTR has been set to $r^{n+1} \cdot r^{n+1}$.

RDOTS

Appears In: POTENT

Meaning: Temporary save of first iteration RDOTR for possible convergence testing (not implemented).

RITER(100)

Appears In: POTENT, TRILIN

Meaning: Potential convergence printer plot storage for up to 100 iterations' worth of RDOTR.

ROUS(17,17,33)

Appears In: TRILIN, INDATA, CHARGE and related routines; POTENT and related routines.

Meaning: Amounts of charge at inner grid points. Right-hand-side of potential equations. This data is also stored in file IROUS. See subroutine CHARGE.

ROUSCN(7)

Appears In: POTENT and related routines.

Meaning: Right-hand-side of linear equations for the conductor potentials.

RTDOT

Appears In: POTENT

Meaning: Monotonic residual dot product with itself, $\tilde{r}\cdot\tilde{r}$, created by potential algorithm one for judging quality of potential convergence.

SSCIJ

Appears In: POTENT

Meaning: $\sum_{I=1}^{MBIAS} \sum_{J=1}^{MBIAS} CIJ(I,J).$

SUN(3)

Appears In: COMMON/SUNVEC/; INOPT, CHARGE and related routines; HIDCEL (see PDIR).

Meaning: User-specified x, y and z components of the sun direction vector (direction-of-view vector for plots) pointing from the satellite center towards the sun (or viewer). See DIR(3). SUN values will be used to calculate new shadowed cell areas only if IAREA > 0.

SWPCIJ

Appears In: POTENT

Meaning: $\sum_{I=1}^{MBIAS} (-SWPCND(I) + CIJSUM(I))$.

SWPSSC

Appears In: POTENT, OBJSPC

Meaning: SWPCIJ - SSCIJ.

TAREA1

Appears In: HIDCEL

Meaning: Temporary save of AREA1(IC) for printing purposes.

TIME

Appears In: CHARGE, TRILIN

Meaning: The time (in seconds) from the beginning of cycle 1.

UCOND(7)

Appears In: POTENT and related routines.
Meaning: Conjugate gradient algorithm u array values for each of up to seven conductors. See subroutine POTENT.

UDOTAU (double precision)

Appears In: POTENT and related routines.
Meaning: Conjugate gradient algorithm dot product $u^n \cdot (Au)^n$. See subroutine POTENT.

UDOTS

Appears In: POTENT
Meaning: Temporary save of first iteration UDOTAU for possible convergence testing (not implemented).

UDOTU

Appears In: POTENT, UDOTUC
Meaning: Conjugate gradient algorithm dot product $u^n \cdot u^n$. Used in calculation of $\tilde{r} \cdot \tilde{r} = u^n \cdot u^n / C^2$ for algorithm one.

VBIAS(7)

Appears In: COMMON/MCOND/; INKEYW, POTENT, PTROUS
Meaning: If conductor I is biased relative to conductor one, then VBIAS(I) is the amount of bias. PCOND(I) = PCOND(1) + VBIAS(I). Otherwise VBIAS(I) = 0. VBIAS is defined in the keyword input file. See subroutine INKEYW.

VFIX(7)

Appears In: COMMON/MCOND/; INKEYW, POTENT and related routines.

Meaning: If conductor I is a fixed potential conductor then VFIX(I) equals the potential at which it is fixed. Otherwise VFIX(I) = 0. VFIX is defined in the keyword input file. See subroutine INKEYW.

VX

Appears In: HIDCEL, PRSPPJ

Meaning: QNX2 + 1000.*DIR(1). x coordinate of "end" of direction-of-view vector pointing from satellite center to viewer. See DIR. Used by PRSPPJ (entry point PPJSET).

VY

Appears In: HIDCEL, PRSPPJ

Meaning: QNY2 + DFAC*DIR(2). y coordinate of "end" of direction-of-view vector. See VX.

VZ

Appears In: HIDCEL, PRSPPJ

Meaning: QNZ2 + DFAC*DIR(3). z coordinate of "end" of direction-of-view vector. See VZ.

WPCOND(1024)

Appears In: OBJDEF, POTENT, TRILIN

Meaning: An array containing the potential coefficients between surface points and their underlying conductors.

W4

Appears In: COPROD, IRCALL, ORCALL and related routines.

Meaning: Geometrical weighting factor determined by nesting level of current grid. For grid IG, W4 = 2**(IG-2).

XDIF

Appears In: HIDCEL

Meaning: Span of 2-D x values for current satellite plot. Used in defining plot user area.

XMAX

Appears In: HIDCEL

Meaning: Maximum 2-D x value for current satellite plot. Used in defining XDIF.

XMAX1(600)

Appears In: HIDCEL and related routines.

Meaning: XMAX1(I) is the maximum 2-D x value of any of the vertices of A1 polygon I.

XMAX2(150)

Appears In: HIDCEL and related routines.

Meaning: XMAX2(I) is the maximum 2-D x value of any of the vertices of A2 polygon I.

XMESH

Appears In: CHARGE, NASCAP, OBJDEF

Meaning: The physical size (in meters) of the inner grid unit.

XMIN

Appears In: HIDCEL
Meaning: Minimum 2-D x value for current satellite plot. Used in defining XDIF.

XMIN1(600)

Appears In: HIDCEL and related routines.
Meaning: XMIN1(I) is the minimum x value of any of the vertices of A1 polygon I.

XMIN2(150)

Appears In: HIDCEL and related routines.
Meaning: XMIN2(I) is the minimum x value of any of the vertices of A2 polygon I.

YCOND(7)

Appears In: POTENT and related routines.
Meaning: Conjugate gradient algorithm y array values for each of up to seven conductors. See subroutine POTENT.

YDIF

Appears In: HIDCEL
Meaning: Span of 2-D y values for current satellite plot. Used in defining plot user area.

YMAX

Appears In: HIDCEL
Meaning: Maximum 2-D y value for current satellite plot. Used in defining YDIF.

YMAX1(600)

Appears In: HIDCEL and related routines.
Meaning: YMAX1(I) is the maximum 2-D y value of any of the vertices of A1 polygon I.

YMAX2(150)

Appears In: HIDCEL and related routines.
Meaning: YMAX2(I) is the maximum 2-D y value of any of the vertices of A2 polygon I.

YMIN

Appears In: HIDCEL
Meaning: Minimum 2-D y value for current satellite plot. Used in defining YDIF.

YMIN1(600)

Appears In: HIDCEL and related routines.
Meaning: YMIN1(I) is the minimum 2-D y value of any of the vertices of A1 polygon I.

YMIN2(150)

Appears In: HIDCEL and related routines.
Meaning: YMIN2(I) is the minimum 2-D y value of any of the vertices of A2 polygon I.

12. SUBROUTINE INDEX

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